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Vol. 7 OCTOBER–DECEMBER, 1953 No. 4

Semi-Popular Articles

Vanilla—Its Botany, History, Cultivation and Economic Import — Donovan S. Correll

American Witch Hazel—History, Nomenclature and Modern Utilization — Edmund H. Fulling

A Genic Substitute for Isolation in Hybrid Corn Seed Production — Oliver E. Nelson, Jr.

Utilization Abstracts

Wood Floor. British Guiana Woods. Bagasse Paper.
Rice Bran Oil Wax. Osage Orange
Antioxidant. Camphor.

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Vanilla—*Its Botany, History, Cultivation and Economic Import*[1]

From the secretly prepared chocolate-flavoring condiment of the Aztec emperor, Montezuma, to the ice cream-flavoring ingredient of today, vanilla has for four centuries been an important item in the spice trade of the world. Originally Mexican, about 90% of the world's 1,000 annual metric tons of vanilla "beans" come from Madagascar, nearly 50% of which are consumed in the United States.

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[1] A revision of the writer's paper published in Lloydia 7: 236–264. 1944. Figures 2, 4 through 17, 28, and 34 through 39, by courtesy of McCormick and Company; figures 18 through 27, photographs by Garcia; figures 29 through 33, taken from Childers and Cibes (1948).

[2] Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture.

Importance and Nature

The most important and famous flavoring substance, or spice, which the Americas have contributed to the world is vanilla. This is today the favorite fla-

voring material in the United States, where normally 40 to 50 percent of the world's vanilla beans, or 450 to 550 metric tons (2,204.6 pounds each), are consumed annually. Since vanilla is a tropical crop, the United States is entirely dependent upon other regions for this natural product. Climatic and edaphic conditions in Puerto Rico, however, are congenial to the vanilla plant, and experience there has shown that the island is potentially capable of supplying most, if not all, of this essential flavoring substance for our domestic needs.

Vanilla is obtained primarily from the fully grown but unripened fruits, or "beans", of a climbing orchid, *Vanilla planifolia* Andrews (*V. fragrans* (Salisb.) Ames), that have been subjected to a fermentation-curing process to produce the characteristic aroma which makes this flavoring so valuable. The finished product is an extract blended with alcohol, pure water and, in some cases, glycerin and sugar.

The substance chiefly responsible for the peculiar fragrance and flavor of the vanilla bean is vanillin ($C_8H_8O_3$). This was first isolated from vanilla by Gobley in 1858. He found that the so-called givre of vanilla was due to vanillin crystals and not to benzoic acid as was then believed (20). Vanillin, which was first made artificially by Tiemann and Haarmann in 1874, is a relatively simple substance that has been synthesized on a commercial scale from coniferin, eugenol and other sources. Cured vanilla beans, however, have an aroma and flavor not fully duplicated in synthetic vanillin, and the occurrence of subsidiary substances, including at least one strongly aromatic ester (61), is the decisive factor in favor of natural vanilla as a flavoring.

Free vanillin is not present in the beans when they are harvested. It is developed as a result of enzyme action on several glucosides, either during the natural ripening of the beans on the vines or by a curing process. White needle-shaped crystals of vanillin accumulate on the outside of the beans when they are stored in bundles after curing. The crystals are half to one cm. in length. Additional vanillin occurs dissolved in a dark brown oleo-resinous secretion surrounding the seeds in the center of the bean (61). The vanillin content of the beans has been found to vary according to where they are grown, from 1.5% in Mexico to 2.7% and higher in Java. First quality Bourbon beans contain about 2.3% vanillin.

The percentage of vanillin content, however, is not necessarily proportional to the quality of the beans and does not determine their ultimate value, nor are the most strongly aromatic beans always those with the highest vanillin content. As noted above, the subsidiary substances inherent in the fruit greatly influence the aroma of vanilla. Besides vanillin, the beans are known to contain vanillic acid which is odorless, about 11% of a fixed oil, 2.3% of a soft resin, sugar, gum and oxalate of lime (32), as well as some wax, fat, coloring matter and mineral constituents. The composition of vanilla is not yet completely understood, vanillin being the only constituent whose chemistry has been thoroughly investigated.

Taxonomy

Vanilla is a tropical genus of the family Orchidaceae. About 50 species have been described, only three of which (*V. planifolia* Andrews, *V. pompona* Schiede, *V. tahitensis* J. W. Moore) are of commercial importance as sources of vanilla. With the exception of those orchids grown and sold in the floral industry for the beauty and singularity of their flowers, these species of *Vanilla* are the only orchids of any real economic importance.

Vanilla planifolia. This species, the principal commercial source of vanilla,

is a coarse vine that in nature climbs to the tops of tall trees. The plant may be briefly described as follows: Stem simple or branched, long, flexuous, succulent, green, producing opposite the leaves twining adventitious aerial roots by which it clings to trees and other supports; leaves succulent, nearly sessile, oblong-elliptic to narrowly lanceolate, acute to acuminate, 9 to 23 cm. long, 2 to 8 cm. wide; racemes axillary, consisting of as many as 20 or more flowers which are greenish-yellow and inconspicuous; flowers composed of three sepals, three petals and a central organ known as the " column " (the united stamen and pistil), with one of the petals modified and enlarged to form the lip; sepals and petals almost linear to oblong-oblanceolate, obtuse to subacute, 4 to 7 cm. long, 1 to 1.5 cm. wide; lip trumpet-shaped, attached almost to the apex of the column which it envelops, somewhat 3-lobed above, 4 to 5 cm. long, 1.5 to 3 cm. wide at the widest point, with longitudinal verrucose lines or papillae on the disc and a tuft of hairs about the middle of the disc, retuse at the apex and irregularly fringed on the revolute margin; column hairy on the inner surface, about 3 cm. long; fruit a capsule (commercially known as a " bean "), narrowly cylindrical, 1 to 2.5 dm. long, 8 to 14 mm. in diameter.

This species, the true vanilla of commerce, is now thought to be indigenous to southeastern Mexico, Guatemala, British Honduras, Honduras, Nicaragua, Costa Rica, El Salvador, Panama, the West Indies, Colombia, Venezuela, Surinam, British Guiana, French Guiana, Ecuador, Peru and Bolivia. It occurs as a non-persistent waif in Florida and probably in most of the tropics and subtropics of the world, where it is also widely cultivated.

Vanilla pompona. A less important source of natural vanilla. It is known as " vanillon " and as " South American ", " West Indian " or " pompona vanilla ", and produces shorter, thicker beans. It resembles *V. planifolia* except that its leaves are larger, being 15 to 28 cm. long and 4 to 11.5 cm. wide. The green-yellow flowers are larger and more fleshy, and the lip has a tuft of imbricating scales, instead of hairs, in the center of the disc. The beans are cylindric and more flesh-thickened, being 15 to 17.5 cm. long and 2.5 to 3.3 cm. in diameter. They are inferior in quality and, consequently, command a lower price.

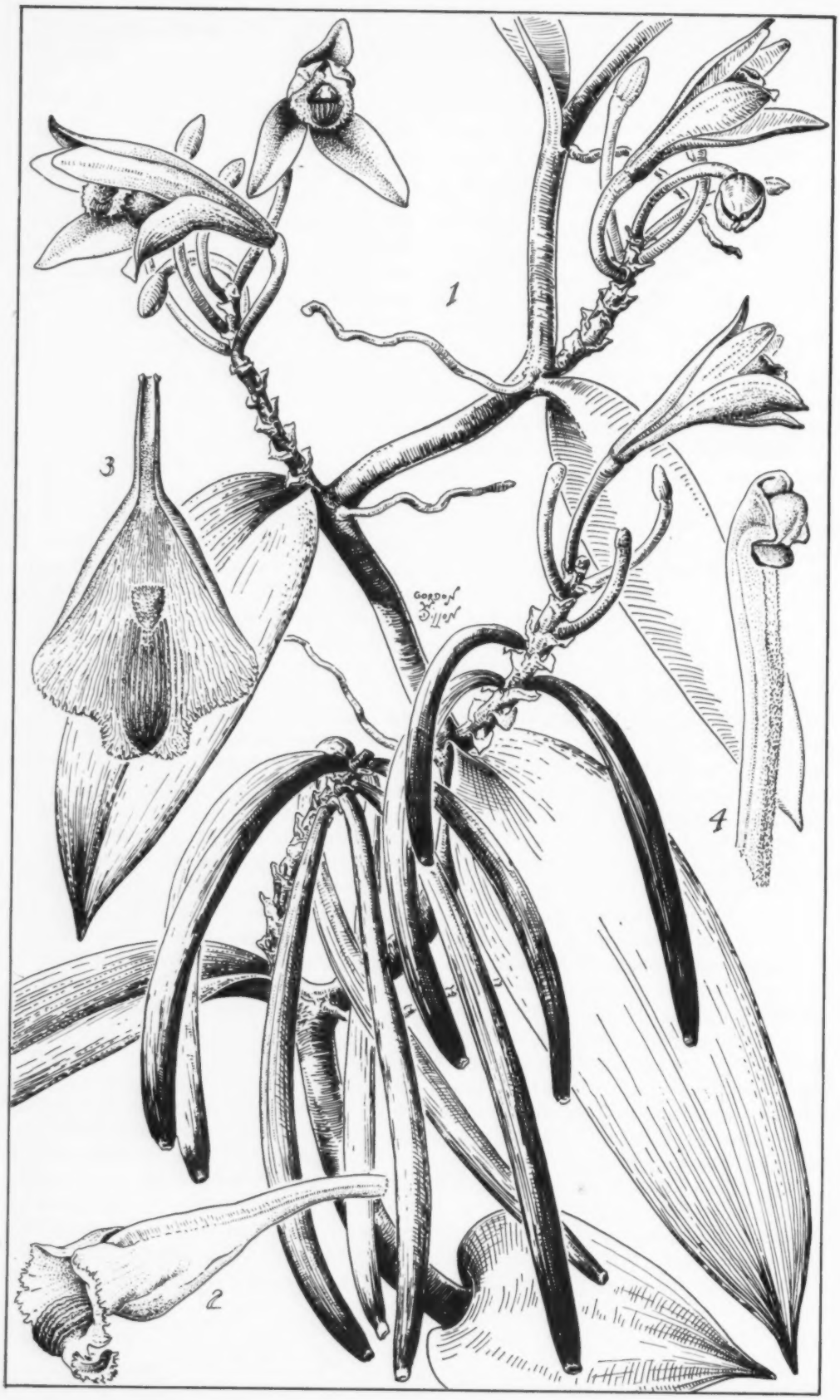
This species is indigenous to southeastern Mexico, Central America, Trinidad and northern South America. It is cultivated primarily in Guadeloupe, Dominica and Martinique. Attempts to cultivate it have been made in other parts of the world, but little is known regarding the results.

Vanilla tahitensis. The Tahiti Vanilla differs from *V. planifolia* in having more slender stems, narrower leaves, longer perianth segments, a lip that is shorter than the sepals and shorter pods. The reddish-brown beans are 12 to 14 cm. long, up to 9 mm. in width, broad in the middle and tapering toward each end.

This species is indigenous to Tahiti. It is cultivated there and in Hawaii.

Other Species. Other species of *Vanilla*, concerning which there is little information available, have possibilities of producing vanilla for commerce. According to Rolfe (55), Gardner commented in collecting *V. Gardneri* Rolfe: " This is the plant which yields the Vanilla (Banilha of the Brazilians) in Brazil ". This species is thought to be the source, to some extent, of what is known in commerce as " South American Vanilla ".

The fruits of *V. appendiculata* Rolfe from British Guiana are said to retain a distinct aromatic odor for 25 years or more after having been collected (55), and the beans of *V. phaeantha* Reichb. f., which has been cultivated in places in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GORDON
DYLLON

the West Indies, possess some perfume. Presl, in describing *V. odorata* from northern South America, noted that, although the fruits had been collected 36 years previously, they still retained their aromatic fragrance. Rio vanilla, said to be obtained from *V. palmarum* Lindl. in the province of Rio de Janeiro, Brazil, and Guiana vanilla, said to be obtained from *V. guianensis* Splitgerber, are, at most, products of inferior quality. It is quite possible that these poorly known and apparently less valuable vanillas are used as adulterants of the true Mexican vanilla, *V. planifolia*. The vanillon, *V. pompona*, is commonly used for this purpose. In Mexico the Indians are said to eat the fruits of wild vanilla, known to them as "vanilla platáno", which is reported to be a smaller plant with larger leaves than *V. planifolia* (26). The botanical identity of this plant is unknown.

Monographic Study. Although the writer has followed the traditional assumption, based mostly on historical evidence, that *V. planifolia* is the principal plant cultivated throughout the world, he is not fully convinced that this is entirely true. It is hoped that before long a satisfactory factual basis will be established regarding the species of vanilla now under cultivation as well as those found in the wild. No monographic work has ever been done on the entire genus. The nearest approach to such was the revision of the genus published by Rolfe in 1896. This revisionary work consisted primarily of a literature survey. It is the writer's intention to make a systematic study of the genus, based not only upon literature but upon living plant material and herbarium specimens, and an appeal is herein made for cooperation and help in this work [3].

[3] Receipt of botanical specimens for the herbarium and of flowers for analysis preserved in alcohol or some other medium, of living plant material for propagation and study, of photographs and of all pertinent data regarding the plant, such as flower color, fruits (whether odoriferous or not), habit, habitat, would be greatly appreciated. Please forward all such material to the author at Inspection House, U.S.D.A., 224 12th Street, S.W., Washington, D. C.

General History and Distribution

The history of vanilla is replete with adventure and romance. Bernal Díaz, a Spanish officer under Hernándo Cortés, was perhaps the first white man to take note of this spice when he observed Montezuma, the intrepid Aztec emperor, drink "chocolatl", a beverage prepared from pulverized seeds of the cacao tree, flavored with ground vanilla beans which the Aztecs call "tlilxochitl", derived from "tlilli", meaning "black", and from "xochitl", interpreted here as meaning "pod" [4]. Vanilla beans were considered to be among the rarer tributes paid to the Aztec emperor by his subject tribes. Cortés was subsequently (in 1520) [5] introduced by Montezuma to his first cup of chocolate, served according to legend in golden goblets, with spoons of the same metal; but the Aztecs jealously guarded their secret—the flavoring principle of the drink. After the vanilla ingredient was finally discovered the Spaniards imported vanilla beans into Spain, where factories were established as early as the second half of the

[4] In the 1651 edition of Hernández's work (Rerum Medicarum Novae Hispaniae Thesaurus) this name was interpreted to mean "black flowers". The flowers of this species, however, are greenish-yellow. This fallacy concerning the color of the vanilla flowers remained in literature for many years.

[5] Morren (1839) states that vanilla was brought to Europe as a perfume about the year 1510 at the same time as indigo, cochineal and cacao, and ten years before the advent of tobacco. These products were doubtless picked up by Spanish vessels that reached Mexico before the arrival of Cortés.

FIG. 1. *Vanilla planifolia*. 1: Habit, ×½; 2: Lip, in natural position, side-front view, ×1; 3: Lip, spread open, ×1; 4: Column, side-front view, ×2. *Drawn by Gordon W. Dillon.*

sixteenth century for the manufacture of chocolate, flavored with vanilla. Thus vanilla may be considered a by-product of the Spanish conquistadors' search for the hidden wealth of the Americas, a by-product which is today one of the most important of the minor agricultural activities in Mexico, where many persons are employed in the cultivation and handling of vanilla beans. In addition, more than 20,000 persons are said to be engaged in this occupation in the French Empire (20), as well as thousands of others employed throughout the world in this and other industries which are more or less dependent upon vanilla. The salaries and wages paid in the vanilla industry are said to be among the best in Mexico.

Bernardino de Sahagún, a Franciscan friar, who arrived in Mexico in 1529, was perhaps the first to write about vanilla when he stated that the Aztecs used "tlilxochitl" in cacao, sweetened with honey, and that they sold vanilla spice in their markets. His work, "Historia General de las Cosas de Nueva España", originally written in the Aztec language, was not published until 1829–30 in Mexico, 300 years after Sahagún's arrival in that country. The first observation of botanical interest, however, was made

FIG. 2. Mural at McCormick & Company's Little Theater.

by Carolus Clusius in 1605 (p. 72), in his "Exoticorum Libri Decem", where he described and gave the name *Lobus oblongus aromaticus* to some dried vanilla beans which he had received in 1602 from Hugh Morgan, apothecary to Queen Elizabeth. These beans were considered to be fruits of *V. planifolia*, the true Mexican vanilla, although nothing seems to have been known of their native country or uses. This same Morgan was the first European to suggest vanilla as a flavoring in its own right, a use already practiced by the Aztecs.

In 1571–77 Francisco Hernández was sent on a mission to Mexico by Philip II of Spain. While in Mexico, Hernández became an authority on vanilla, and in his work noted above, first published in Rome in 1651, he not only described and named the plant *Araco aromatico*, but he figured a vanilla branch with leaves and two beans growing upon it (p. 38). He also recorded its native name, "tlilxochitl", and noted that it was held in high esteem by the Mexicans, not only for its pleasant taste and aroma but also because of its supposed healing qualities. A few years later, in 1658, William Piso wrote that, because of their fragrance, the Spaniards used the beans, which they called "vaynilla", meaning

38 RERVM MEDICARVM NO. HISP.

De TLILXOCHITL seu flore nigro Araco Aromatico. Cap. XV.

VOLVBILIS herba est *Tlilxochitl*, foliis Plantaginis prędita, sed pinguioribus, & longioribus, viroreq. infectis saturato, singulis ex vtraque parte caulis alternatim exorientibus; ac siliquis longis, angustis, & penè teretibus, olentibus muscum, aut Balsamum indigenum, nigrisq. vnde nomen. Calidis regionibus prouenit, humętibusq. Arbores amplectitur, & prędictas siliquas verno tempore profert. Calidæ hæ, sunt ordine tertio, addiq. solitæ *Cacaoatl*, & *Mecaxochitl*. siliquæ binæ ex aqua resolutæ, & potatæ vrinam cient, menstrua euocant. cum *Mecaxochitl* partum accelerant, ac secundas, mortuumq. fœtum trahunt, ventriculum calefaciunt, & roborant, flatum discutiunt, humores crudos concoquunt, atque attenuant, cerebro vim addunt, & vtero auxiliantur. Aduersus venena frigida, gelidosq. venenatorum ictus, eædem siliquæ dicuntur esse remedio.

Folium longum est vncias vndecim, latum sex, siliqua vero longa vncias sex, crassa digitum vnum.

FIG. 3. One of the first descriptions and illustrations of vanilla—the "Tlilxochitl" (*Araco aromatico*) of Hernández (1651).

"little pod", as an ingredient in the manufacture of chocolate (Historiae Naturalis et Medicae Indiae Orientalis, p. 200). This is supposed to have been the first use of the word "vaynilla", from which the scientific name of the genus is derived. Francesco Redi in 1675 studied some dried fruits of vanilla under a microscope and described the fruit and seeds (41). William Dampier, in his "A New Voyage Round the World", gave some valuable information about vanilla plants which he observed growing in 1676 on the Bay of Campeche in southern Mexico, and in 1681 at Boca-toro in Costa Rica. He stated that the beans were collected by the Indians who sold them to the Spaniards. He also described the method of curing the fruit as follows:

> "We found a small Indian village, and in it a great quantity of Vinello's drying in the sun. The Vinello is a little Cod full of black seeds; it is 4 or 5 inches long, about the bigness of the stem of a Tobacco leaf, and when dried much resembling it: so that our Privateers at first have often thrown them away when they took any, wondering why the Spaniards should lay up Tobacco stems. This Cod grows on a small Vine, which climbs about and supports itself by the neighboring trees; it first bears a yellow Flower, from whence the Cod afterwards proceeds. It is first green, but when ripe it turns yellow; then the Indians (whose manufacture it is, and who sell it cheap to the Spaniards) gather it, and lay it in the sun, which makes it soft; then it changes to a Chestnut colour. Then they frequently press it between their fingers, which makes it flat. If the Indians do anything to them besides, I know not, but I have seen the Spaniards sleek them with Oyl" (p. 234).

The above observation was made at Caibooca on the coast of the Bay of Campeche, Mexico. Dampier further states that vanilla grew abundantly at Boca-toro, Costa Rica, where he had unsuccessfully attempted to cure the beans. He could not obtain this information from the Spaniards and he concluded that the Indians had some secret in the matter. He wrote:

> "Could we have learnt the art of it, several of us would have gone to Bocca-toro yearly, at the dry season and cured them, and freighted our vessel. We there might have had Turtle enough for food and store of Vinello's . . . . They are commonly sold for 3 pence a Cod among the Spaniards in the West Indies, and are sold by the Druggist, for they are much used among Chocolate to perfume it. Some will use them among Tobacco, for it gives it a delicate scent. I never heard of any Vinello's but here in this Country about Caibooca and at Bocca-toro" (p. 235).

The genus *Vanilla* was not described until 1703, when Plumier (Nova Plantarum Americanarum Genera, p. 25, pl. 28) enumerated three species from the West Indies but failed to include the Mexican plant, *V. planifolia*. The generic name, *Vanilla*, was not definitely accepted until 1799 when Swartz distinguished two species, *V. aromatica* and *V. claviculata*.

The nomenclatural status of the vanilla of commerce has never been definitely settled to the satisfaction of all botanists. According to Rolfe (55), the only reviser of the genus:

> "The Mexican *Vanilla* had been introduced to cultivation prior to 1739,[6] when the second edition of Miller's 'Gardener's Dictionary' was published, but appears to have been again lost. It was, however, reintroduced by the Marquis of Blandford and flowered in the collection of the Right Hon. Charles Greville, at Paddington, prior to 1807, in which year a flowering specimen was figured and described by Salisbury under the name of *Myobroma fragrans* ('Parad. Lond.,' t. 82), and a year later Andrews published another figure as *Vanilla planifolia* ('Bot. Rep.,' viii. t. 538). Both of these authors wrongly identified the plant with a West Indian species, and both equally failed to recognise in it the true Mexican *Vanilla* of commerce, whose flowers were now figured for the first time."

It is interesting to note that the same plant which flowered in 1807 also pro-

[6] The second edition of Miller's "Gardener's Dictionary" was published in 1733.

duced fruits, at which time Francis Bauer, the famous illustrator, prepared a drawing of the plant showing a fresh fruit. This is the first record of a vanilla fruit having been produced in Europe. How the flower was pollinated and became fertilized is not known. The botanical gardens in Paris and Antwerp were subsequently supplied cuttings from this plant.

ana. Humboldt in 1811 (Voyage de Humboldt et Bonpland 2, pt. 3, p. 437) also gave an interesting account of the culture and preparation of vanilla in the State of Veracruz, Mexico.

Although vanilla as an article of commerce was introduced into Europe the early part of the sixteenth century, it did not appear permanently in horticulture until the beginning of the nineteenth cen-

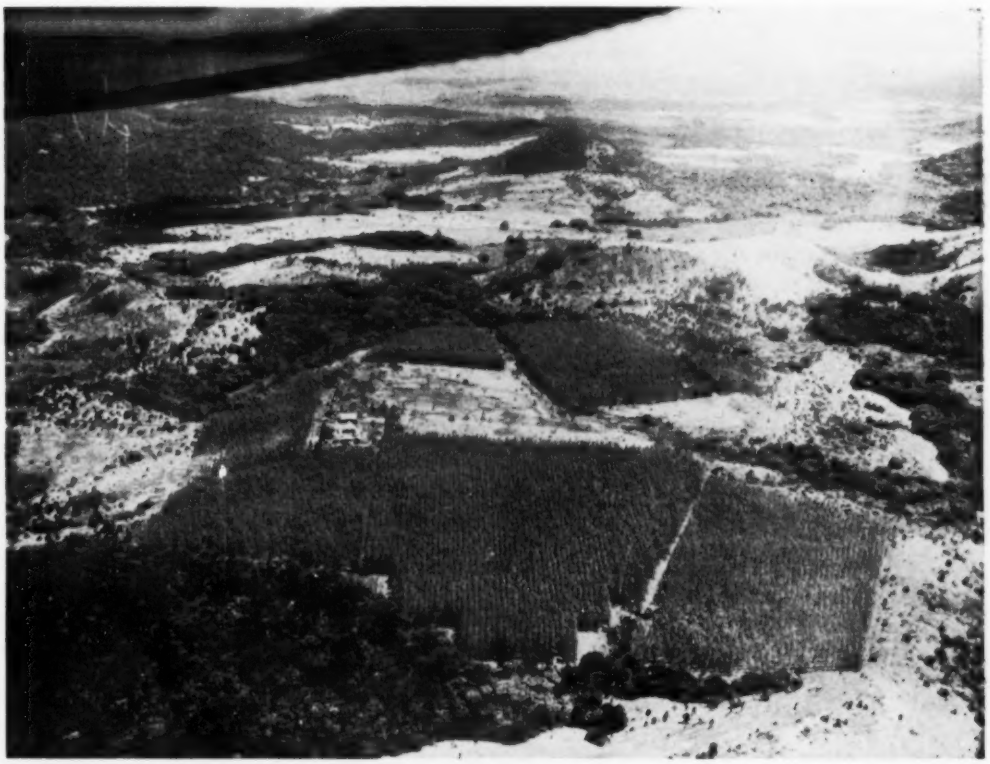


FIG. 4. Vanilla plantation from the air. Filaox (*Casuarina equisetifolia*) used as supports. Madagascar.

Among the principal early authors who described vanilla in its native habitat may be mentioned Fusée Aublet who, in 1775 (Histoire des plantes de la Guiane Françoise 2, Mem. 4, pp. 77–85) not only recorded the methods of cultivation and curing of the fruits but also gave an account of three kinds of vanilla, typified by large, small and long beans, found in the vicinity of Cayenne, French Guitury when, as noted above, it gained attention in 1807 after having flowered and fruited in the collection of Charles Greville.

For more than two centuries Mexico and other regions where *V. planifolia* is indigenous were the only sources of vanilla, since only in these regions was it possible to obtain fruits. Because of the unique adaptation of the flowers of

orchids to insect pollination, only the bees in the regions where the plant grew naturally were apparently able or inclined to pollinate the flowers effectively. The dependence upon, and lack of, such specific pollinating agents retarded for some time the introduction of the plant as a plantation crop into other regions of the world congenial for its growth.

An effort was made to establish vanilla in Java in 1819 when two plants were dispatched to Buitenzorg from the Botanic Garden at Antwerp. Only one of these plants, however, survived the voyage and subsequently produced flowers, but no fruits, in 1825. The botanist Blume (Bijdr., p. 422) described this plant as *V. viridiflora*, although apparently unknown to him it had been derived from the same plant previously described as *Myobroma fragrans* by Salisbury and *V. planifolia* by Andrews. Later, in 1846, vanilla cultivation on a systematic plantation basis was established in Java.

In 1836 Charles Morren of Liége established the identity of the true vanilla of commerce as *V. planifolia* and obtained two large crops of vanilla beans by pollinating the flowers artificially by hand. He attributed the failure of the plants to produce fruit in the eastern hemisphere to the absence of the particular insect or insects which pollinated the vanilla flowers in their native regions. In 1838 Morren's achievement was repeated by Neumann of the Muséum d'Histoire Naturelle in Paris, and several years later, in 1841, a former slave, Edmond Albius, in Réunion discovered a practical method of artificial pollination which is used to this day.

This discovery of a method of artificially pollinating the flowers of vanilla, combined with the possibility of propagating the plants by cuttings, opened the way for its cultivation as a plantation crop on a large scale in the eastern tropics. Madagascar, which normally produces about 75 percent of the vanilla beans grown in the world, is the most important area, with Mexico a poor second. Vanilla is also grown successfully, to a greater or lesser degree, in Réunion (Bourbon), Mauritius, the Seychelles Islands, Tahiti, Guadeloupe, Martinique, Zanzibar, French Congo, Congo Independent State, Puerto Rico, Brazil, Dominica, Cameroons, Sierra Leone, Lagos, San Thomé, Comoro Islands, Ceylon, Java, the Society Islands and the Fiji Islands. It is grown to some degree but has not been too successful nor of commercial quantity in Hawaii, the Philippine Islands, India, Cochin-China, Malay Peninsula, Straits Settlement, Bolivia, Peru, Venezuela, Sumatra, Trinidad and several Central American countries.

The history of the gradual but universal spread of the vanilla of commerce throughout the tropics of the world is meagre and, for the most part, unreliable. According to Ridley (54), vanilla was first introduced into Réunion in 1793, but its cultivation there did not become important until after the sugar cane failure between 1849 and 1856, and did not attain large proportions until about 1874. From Réunion the plant was introduced into Mauritius in 1827, and about 1840 into Madagascar.

Vanilla was introduced into India in 1835, but it was allowed to die out after flowering. Some years later it was again brought to India where it produced fruit, but its cultivation has never progressed in that country. Vanilla is said to have been introduced from Manila to the island of Tahiti by Admiral Hamelin in 1848, and growing it soon developed into a major industry. An unsuccessful attempt was made in 1852 to introduce the plant into the French Congo. It was successfully reintroduced in 1873, but its cultivation has not spread very rapidly. Vanilla growing was started in the Seychelles Islands about 1890 [7], and cultivation in the Comoro Islands was begun

[7] "Vanilla cuttings are said to have been first introduced into the Seychelles Islands in 1866, probably from Bourbon (La Réunion) . . ." (Galbraith (33)).

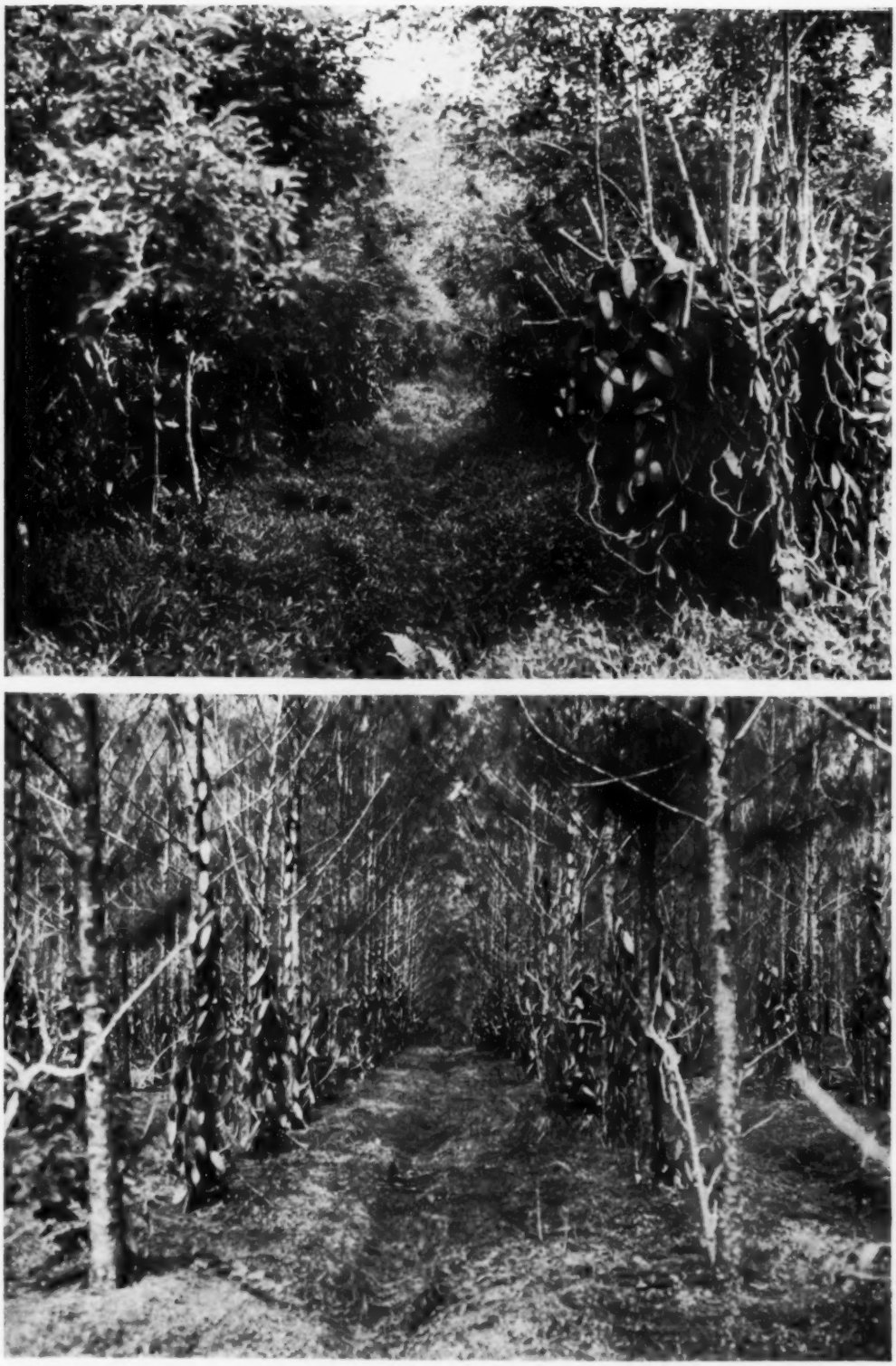


FIG. 5 (*Upper*). Old type vanilla plantation in which a multi-branched broad-leaved species (*Jatropha curcas*) is used as supports. Madagascar.

FIG. 6 (*Lower*). Modern vanilla plantation in which single-stemmed *Casuarina equisetifolia* is used as supports. Madagascar.

in 1893 and very soon spread throughout these islands. By 1886 vanilla production was greater in the Mascarene Islands (Réunion, Mauritius, Rodriguez) and Java than in Mexico (43).

Indian Ocean Islands

Madagascar (including Comoro Islands and Nosy-Bé). As may be noted above, the French, more than any other nation, have developed the vanilla industry in their overseas possessions. Soon after its introduction into Spain, vanilla was replaced by cinnamon as a flavoring for chocolate. In France, however, it remained the favorite, and eventually it came to be used in perfumes, confections and ices. In recent years the French Colonies have produced between 85 and 90 percent of the vanilla beans of commerce, of which 83 percent is produced in Madagascar. More than 20,000 persons are said to be engaged in vanilla production in Madagascar which, in turn, supports several hundred thousand natives in the district of Antalaha. In Madagascar vanilla bean exports are second in value only to those of coffee and tobacco.

Practically all the Madagascar vanilla is grown by Malagasy on little plots and farms, there being very few plantations. The product is bought by middlemen, mostly Chinese, who do much of the classifying and curing, after which they sell the product to exporters who, in turn, do more of the same work and send it, often by air, to their warehouses in Antalaha for further preparation and shipment. The largest profit, after the government takes its export tax, is made by the exporter. The middleman makes a good profit, but the grower's income is very small indeed.

Nearly all of the production is along the east coast north of Tamatave, the business center of the vanilla trade, and the warehouses of the main exporters are at Antalaha. The largest cultivation center, however, is at Andapa, about 100 kilometers northwest of Antalaha, and the crop is gathered there from August to October. Antalaha ranks second in cultivation, crop gathering being from July to September. Sahambava and Vohemar, which are north along the coast, rank next in quantity and have the earliest gathering, from May to July. Petty amounts, perhaps a total of 20 tons, are found at other centers such as Tenerive, Soanierana and Mananara, all on the coast a little north of Tamatave, and at Ambanja on the northwest coast.

New crops are cured for about six months and are salable in eight to 12 months. A vanilla vine begins to produce in about four years. If given a year's rest, it is considered that the vines gain in strength and productivity.

Similarly to other spices grown in Madagascar, such as cloves and black pepper, vanilla is grown by natives on small holdings, and no accurate measurement of the aggregate of these holdings has ever been made. The actual acreage, which has never been ascertained, apparently remains more or less constant from year to year. It was estimated by the Madagascar Agricultural Service that about 6,220 acres were planted to vanilla in 1948. Estimates as high as 55,000 acres for 1949 have been made. This, however, seems highly improbable.

Even with good weather there is always the danger of cyclone damage during the early months of the year, such as those of February 5th and 13th, 1950, which did considerable damage to the vanilla crop in the Antalaha area.

Since the plants flower from October to December in the main vanilla-growing districts, a rather delicate balance in the weather determines the size of the

FIG. 7. Vanilla vine growing on *Casuarina equisetifolia* support. Madagascar.

vanilla crop. If the proportion of rain and sunshine is well balanced, a good crop will be forthcoming; if too much rain falls, plant development goes into the vine instead of the flowers.

Before World War II a large percentage of Madagascar vanilla was shipped to Bordeaux and Marseilles, France, for transshipment to the United States and elsewhere, and French traders in the commodity controlled the local market while realizing non-productive profits from their transshipments. When American vessels began to call at Madagascar ports after the allied blockade of the island was lifted during the war, local producers took advantage of the opportunity to ship their accumulated vanilla stocks directly to the United States. The French government supported these direct shipments by prohibiting exports of vanilla from France to the United States until the end of 1946. When metropolitan traders were again allowed to transship vanilla to the United States at the beginning of 1947, the French government set minimum prices so that Madagascar shippers would not be prejudiced.

During the wartime years large stocks of prepared vanilla beans were built up in Madagascar because of lack of shipping facilities and the allied blockade. In September, 1947, an estimated 1,660 tons of vanilla stock was on hand. This almost doubled the average 876 tons consumed throughout the world annually from 1929 to 1938.

Despite unusually large exports following the end of the war, a surplus of several hundred tons remained in the colony. Local stocks were estimated at from 800 to 1,000 tons in July, 1948. In September, 1948, the Madagascar Government General instituted a stock destruction program, under which a total of 636 tons of prepared vanilla beans were delivered to the government and destroyed by burning by the end of the year when the program was suspended. This destruction of old surplus beans was done so as to assure American buyers that such old stock would not be dumped on the market in the future and to assure potential American importers of the stability of the Madagascar vanilla market.

Toward the end of 1947 American importers held good stocks of vanilla beans, and, when Madagascar officials set a minimum price of $17.00 per kilogram for best quality beans in October, 1947, American importers refused to purchase and the United States market was thus closed to vanilla exporters. This virtual embargo on direct purchases of vanilla beans from Madagascar continued until May, 1949, when price control was abolished, in spite of the official destruction of bad stock and lowering of prices to $11.00 per kilogram in September, 1948, and to $9.00 per kilogram in 1949. The latter prices were set to undercut the then existing price of $12.00 per kilogram for Mexican best quality beans. Mexico in 1948 had taken over about 60 percent of the United States vanilla market.

Madagascar officials want to keep prices steady by means of sound stocks. Of the dozen or more American importers, some want a free market at uncontrolled prices, while others want an assurance of a stability of prices.

In 1947 a Madagascar government official made a study of the vanilla situation to determine how to maintain Madagascar vanilla on a high quality level. It was concluded that in order to do this, enforcement of proper conditioning of the beans was necessary. At the time of the report anything could be sold regarding vanilla beans. Quality had been decreasing yearly primarily because of the following factors: *a*) picking of green pods by theft or fear of theft; *b*) preparation of beans by amateurs (since vanilla is a speculative business, it was considered that only experts

FIG. 8 (*Upper*). Vanilla-pollinating crew. Madagascar.
FIG. 9 (*Lower*). Picking green vanilla beans. Madagascar.

should do the work of curing the beans); *c*) lack of scientific cultivation of the crop; *d*) adulteration of first quality beans by mixing inferior beans.

In 1951 between 500 and 550 tons of vanilla beans were produced in Madagascar as follows: 300–350 tons in Andapa; 100 tons in Antalaha; 60 tons in Sambava; about 40 tons in other areas.

Mascarene Islands (Mauritius, Réunion, Rodriguez). The vanilla industry in Mauritius, which at one time was rather important, has steadily declined in recent years on account of diseases, low prices and other causes until most of the plantations have been abandoned. In Mauritius the best vanilla supports were found to be *Dracaena reflexa*, *Casuarina equisetifolia*, *Jatropha curcas*, *Mangifera indica* and *Persea gratissima* (51).

After the last war Réunion vanilla was reserved for France, since it was not acceptable to American importers.

Seychelles Islands. Before 1900 the Seychelles Islands' prosperity largely depended on vanilla. Disease, however, practically wiped out the crop, and vanilla production was almost nil until about 1940 when vanilla again became an export product of the islands.

Latin America

Mexico. Although today Mexico is not the greatest producer of vanilla, it is still the classical and historical center of the crop. For this reason, primarily, vanilla production in Mexico will be treated in greater detail than that of any other region. Also, the writer has visited the Mexican vanilla country and is more familiar with procedures there. Since Mexico is the original home of vanilla, many capable authors have written about the industry in that country. The present writer has, where necessary, drawn liberally from these reports so as to make the story of vanilla in Mexico as complete as possible. It must be stated, however, that production procedure is basically similar throughout the world where vanilla is grown commercially.

Production of vanilla on a commercial scale in Mexico is limited to a well-defined area covering part of central Veracruz and northern Puebla. All of the growing districts and principal curing and trading centers are located within a radius of not more than 65 kilometers from the town of San José Acateno.

The three leading vanilla-growing districts are at the present time, in the order of importance: Papantla, in the State of Veracruz; San José Acateno, in the State of Puebla; Gutiérrez Zamora, in Veracruz. Papantla produces at least 40 percent of all the vanilla grown in Mexico. This town is still the chief center of Totonaco Indian culture, and practically the entire production in the area is carried out by these Indians. About 38 kilometers east of Papantla is Gutiérrez Zamora, located on the northern bank of the Tecolutla River. Gutiérrez Zamora is an important vanilla curing center but ranks only third as producer of green vanilla beans. Approximately 20 percent of the country's production is grown there. The second leading vanilla growing district, San José Acateno, is about 65 kilometers south of Papantla. This district produces approximately 30 percent of the total. The remaining ten percent comes from neighboring areas, including San Rafael and Martínez de la Torre.

The Totonaco Indians have an inherent knowledge of the conditions needed for growing and curing vanilla. They appear to have an intuitive understanding as to how much sun and shade is essential for best yield and quality. To the average observer, a Totonacan-vanillery resembles an unkept forest, but from these unpretentious holdings come the world's finest vanilla beans. The plants flower in April and May, and the

FIG. 10 (*Upper*). Market center for green vanilla beans. Madagascar.
FIG. 11 (*Lower*). Weighing green vanilla beans at the market center. Madagascar.

pods develop in October or November. The harvest usually takes place between November and January.

Curing of the beans is done primarily in San José Acateno, Papantla and Gutiérrez Zamora. Each of these localities is responsible for approximately one-third of the total quantity cured in Mexico. There is considerable competition among the large curers for the available supplies of green beans, and, as a result of this competition, the origin of the beans cured at each of these three centers changes from year to year. The bulk of the San José Acateno production is cured there, with only a small proportion going to Papantla to be cured, and vice versa. Gutiérrez Zamora depends largely on beans grown there and in Papantla, but also receives some supplies from San José Acateno.

The principal vanilla dealers are located at Papantla, Gutiérrez Zamora and Teziutlán. The latter is not a vanilla-growing center, but dealers there control most of the production of San José Acateno. Teziutlán rose to importance as a vanilla trading center in the days before the building of the highways, when the chief means of transportation of the beans was the railway and Teziutlán was the railway station nearest to the vanilla region.

During the past decade construction of excellent highways linking the vanilla-producing areas with Mexico City, Veracruz and other important centers has greatly affected the Mexican vanilla industry. Until a few years ago, only trade routes were available to exporters of vanilla, either down the Tecolutla or Nautla rivers and thence by coastwise schooner to Veracruz or Tampico, or by mule back over mountain trails to the railhead at Teziutlán, and thence by railroad to Veracruz or Laredo. Improved transportation facilities have resulted in a shift in the vanilla-producing areas. Dependence upon a crop such as vanilla, which can be stored for long periods, is no longer necessary, and other crops, such as bananas, have replaced vanilla to some extent in the lower-lying regions, for instance, San Rafael and Gutiérrez Zamora. Vanilla, however, still holds its own in the hilly country between Papantla and San José Acateno.

The opening up of the vanilla country made available more imported consumer goods for purchase by the natives—a desire for a higher standard of living resulted. This fact, plus labor competition with the nearby increasingly important petroleum center of Poza Rica has resulted in an increase in both the cost of production of the green vanilla beans and the cost of the curing process.

Before the advent of modern transportation, Mexican vanilla production was a picturesque and highly individualistic occupation. The Totonaco Indians, one of the three tribes who were supposed to grow vanilla for the Aztecs, were among the first to pledge allegiance to Cortés and consequently were left undisturbed in the private ownership of their individual tracts. Through the years vanilla culture in Mexico was carried on almost entirely within their lands. These lands lie for the most part on the first rising ground on the coastal plain of the Gulf of Mexico in southeastern Mexico. Although today other peoples are more and more drawn into vanilla production, the Totonaco Indians are still the main producers. About 10,000 Indians are said to produce most of the vanilla exported from Mexico. The skill and thrift of the Totonaco Indian make him a prime factor in the Mexican vanilla industry. He is a good bargainer and demands payment in silver which he may bury in the ground. He also controls the production of the beans, increasing or reducing his crops with the rise and fall in prices. The beans are generally sold to the larger export houses or to their traveling agents.

FIG. 12 (*Upper*). Dipping green vanilla beans in hot water. Madagascar.
FIG. 13 (*Lower*). Green vanilla beans after dipping in hot water. Madagascar.

As noted above, the States of Veracruz and Puebla produce about 98 percent of the vanilla in Mexico. Rich volcanic soils and climatological factors combine to make this area perhaps the ideal region in the world for vanilla culture. Most of the plantations are at an altitude of about 1,000 feet above sea level. Besides the above regions, other vanilleries of minor importance are found in the States of Chiapas, San Luis Potosí, Oaxaca, Tabasco and Michoacán. In 1920 it was estimated that more than 50,000 persons were employed in Mexico in the cultivation, handling and extraction of vanilla (26). It is highly improbable that this number of people is engaged in the industry today.

West Indies. Although vanilla has been grown for many years throughout the West Indies, where there is abundant land for this crop, it has not amounted to much. Several factors, including diseases, high cost of labor and cultural difficulties, have been obstacles to the development of a vanilla industry in this region. The following notes summarize what is known of vanilla production on several islands in the West Indies.

Puerto Rico. Although *Vanilla planifolia* is considered to be indigenous to Puerto Rico, according to McClelland (46), plants from which commercial plantings were later derived in Puerto Rico came from two introductions. The first was brought from Mexico before 1909, in which year a second importation was made by the Federal Experiment Station in Puerto Rico from the United States Plant Introduction Garden in Florida. By means of vegetative propagation a small vanillery was soon developed by McClelland at Mayaguez, from which stock stem cuttings were distributed to numerous farmers on the island. Only a few, however, developed vanilleries.

Since the above introduction of vanilla in 1909, the Federal Experiment Station at Mayaguez has conducted a research program on vanilla with the goal of making it at least a minor agricultural crop for the highland farmers so as to supplement or partially replace coffee that is grown in this region. During this period a number of papers dealing especially with the agronomy and curing phases of vanilla have been published by members of the staff at Mayaguez. This work culminated in 1948 with the publication of Childers and Cibes' comprehensive survey of vanilla culture in Puerto Rico, from which publication much of the information included here has been taken concerning Puerto Rico.

It has been amply demonstrated that vanilla can be grown profitably in Puerto Rico provided the vanillery is located on a suitable site and conscientious management is given to the work. It has been determined through research that the basic requirements for successful growing of vanilla in Puerto Rico are to continually maintain a heavy mulch, admission of sufficient but not excessive light through the shade trees, proper pruning of the support trees, and moderate but not excessive pollination. Any treatment other than the above results in vines which are weak, low-producing, short-lived and susceptible to root rot. Under natural conditions vanilla appears to grow best in those sections of Puerto Rico where the rainfall is about 75 inches or more per year and fairly well distributed from one month to the next. It has been grown most successfully in the region of Morovis.

Puerto Rico has available land in regions suitable for growing vanilla, especially in the coffee areas, as noted above, and continued effort has been made for some years to establish this industry on the island so as to help supply the markets of the United States. Encouragement should also be given this crop in other suitable areas of tropical America. The knowledge concerning

FIG. 14 (*Upper*). Sunning vanilla beans after dipping in hot water. Madagascar.
FIG. 15 (*Lower*). Sorting vanilla beans after curing. Madagascar.

this crop, derived through research by members of the Federal Experiment Station at Mayaguez, should be useful for all tropical America. McClelland in 1919 first strongly advocated growing this crop in Puerto Rico.

In 1924, according to Childers and Cibes, one vanilla grower in Villalba sold 1,375 pounds of cured vanilla beans at the relatively high price of $10.00 per pound. In October, 1928, however, when this grower's plantings had become well established, the San Felipe hurricane swept the island with disastrous consequences, and, like many other planters, he abandoned both his coffee and vanilla enterprises.

In 1935 interest in vanilla was again revived when the Federal Emergency Relief Administration initiated a project for extensive plantings of vanilla in the coffee districts. Cuttings of vanilla and the support tree, dwarf bucare, were distributed to some 40 farmers. Supervision and instruction on the best methods of establishing a vanillery were given to these farmers. The disadvantages of growing the crop in Puerto Rico were found to be lack of experience in curing and packing methods, difficulty in financing the undertaking, lack of an established reputation, damage caused by root diseases (shared by all vanilla-producing countries) and comparatively high cost of labor.

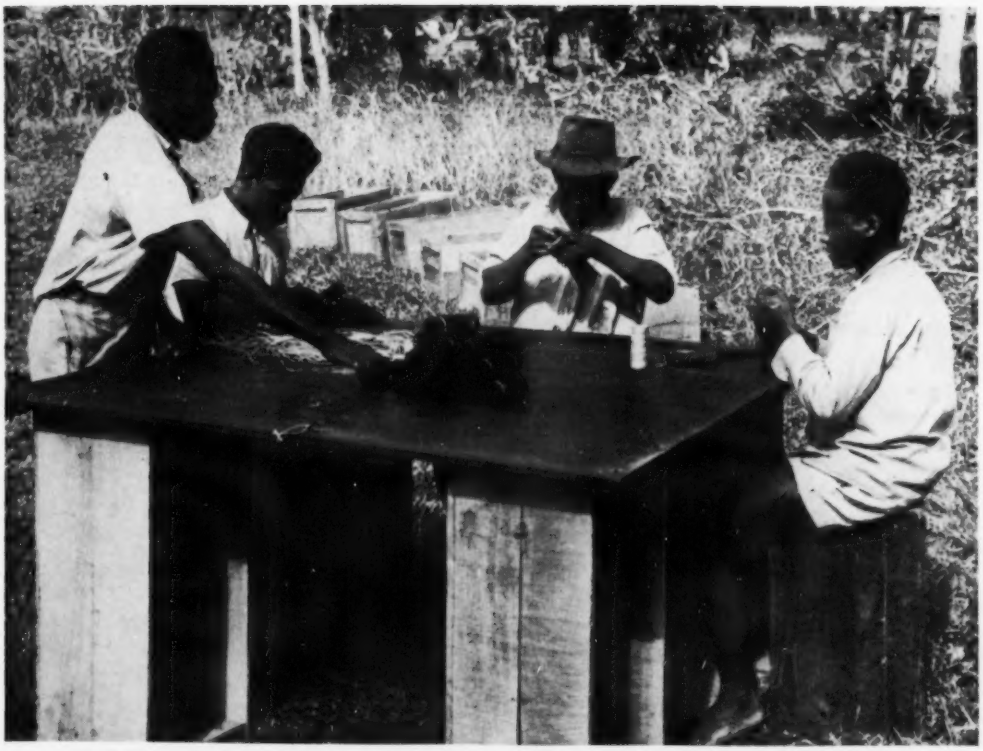
A few years later the above agency was liquidated, and in its place the Puerto Rico Reconstruction Administration was organized. This latter agency intensified the distribution of propagating material until about 106 acres were planted to vanilla by 1937. Three years later there were 434 acres in vanilla owned by 168 farmers, and in 1941 Puerto Rico exported 1,778 pounds of cured vanilla beans to the United States. A central cooperative curing plant was constructed at Castañer, and a cooperative association was organized by the vanilla growers. Through this cooperative, uniform classification, curing and packing, the lack of which had been the chief factor in prevênting the island from becoming a production center, were brought about.

Beginning April 1, 1946, the grower's organization, Cooperativa Cosecheros de Vainilla de Puerto Rico (the Vanilla Grower's Cooperative of Puerto Rico), leased the curing plant from the Puerto Rico Reconstruction Administration for a ten-year period. A buying option clause was inserted in case purchase of the curing plant by the grower's organization seemed desirable and possible.

Since 1935 vanilla production in Puerto Rico has increased definitely, although the industry still is relatively small. In 1944–45 the value of the crop rose to $40,000. The most recent survey, before 1948, showed a total of about 144 active growers, the majority of whom were associated with the vanilla grower's cooperative. The largest producer among these growers sold 2,332 pounds of fresh beans to the Cooperative in 1944–45.

GUADELOUPE, F. W. I. G. Chatenet, of the Direction des Services Agricoles de la Guadeloupe, states in a letter that the principal localities producing vanilla in Guadeloupe are as follows in order of importance: Pointe-Noire, Trois-Rivières, Saint-Claude, Gourbeyre, Capesterre Gpe, Deshaies, Vieux-Habitants, Bouillante, Baillif. He also reports that in 1950 the total production of vanilla was 12 tons, all of which was exported to the United States and Canada. In 1951 the production was 15 tons, and up to October, 1951, about half had been exported to the United States and Canada.

Up to 1928, a record year with 34 tons produced, the average production was 25 tons a year. However, as with coffee and cacao, the vanilla cultivation, already in decadence in Guadeloupe, suffered a crippling blow from the 1928 hurricane, one of the worst experienced



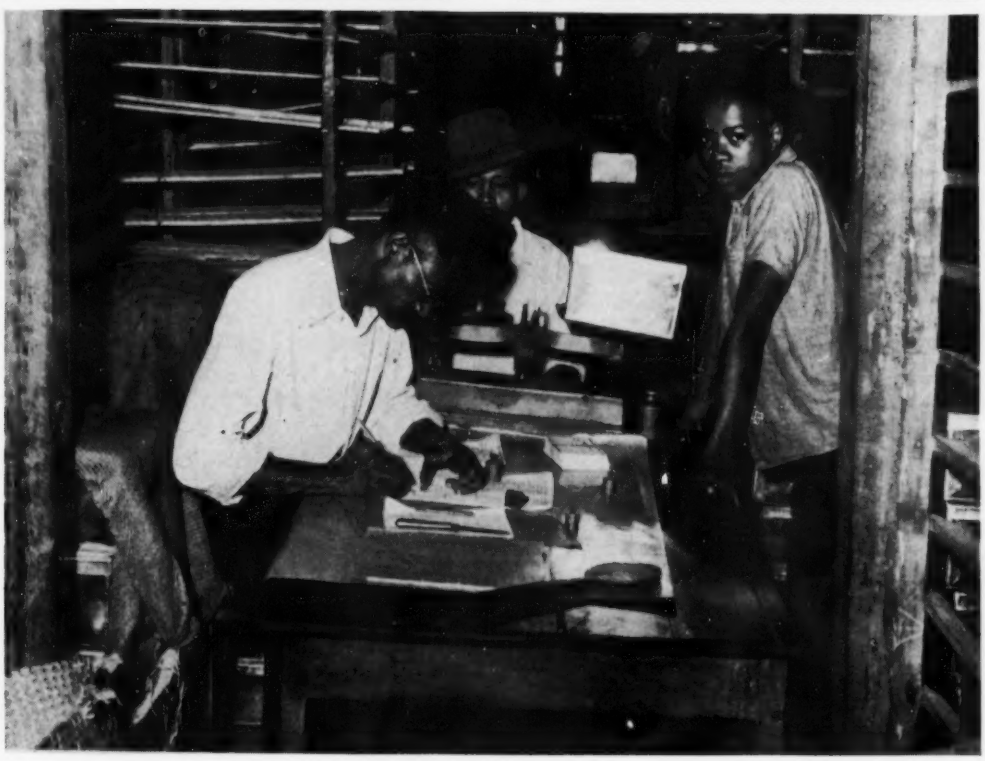


FIG. 16 (*Upper*). Bundling vanilla beans after sorting. Madagascar.
FIG. 17 (*Lower*). Weighing vanilla beans after packaging. Madagascar.

by the island in recent times. The banana, which now largely dominates the economy of southern Guadeloupe proper, has steadily replaced the above crops.

Dominica, B. W. I. In 1947 L. H. Narodny stated that the 50,000 pounds of cured vanilla beans comprised the most valuable of Dominica's exports in 1945, and in 1947 vanilla provided the main source of income in the Carib Reserve on Dominica. The crop, however, is cultivated primarily by negro peasants in their small gardens, where some have only a single vine. As in several other areas of the world, vanilla became of importance or of increased importance in Dominica because of World War II which resulted in a temporary loss of Madagascar beans to the world market. In fact, in 1945 and 1946 the value of vanilla beans exceeded that of limes and lime products, the traditional major export crop.

In a recent letter Narodny gives the annual vanilla production in Dominica from 1918 to 1950 as 796 pounds for 1918 and more than 45,000 pounds each for 1944, 1945, 1946, 1948 and 1949. The highest year was 1949 with 68,823 pounds; the lowest, 1933 with 21 pounds. These figures represent exports of beans on which duty was paid, not total production, especially since some smuggling with Guadeloupe takes place to obtain barter goods such as cloth. Narodny's letter of December, 1951, contains the following pertinent paragraph:

> "Production now is very small, probably about 12,000 lbs. of cured beans, largely due to the depressed price of green beans (about 15¢ a lb.). Any rise in price would show immediate increase in production, as probably well over a million producing vines are now growing unattended in the forest. Banana cultivation has been stimulated by a five-year contract at a guaranteed minimum price of 3½¢ W. I. per lb. which yields far greater profits to the peasant than vanilla. Dominica is therefore a very large potential supplier if prices should double, something which was not possible in the previous two decades. The crop is grown entirely by peasants on average plots of five acres or less. Curing is now done by three merchants".

St. Lucia and St. Vincent, F. W. I. The greatest difficulty experienced in trying to cultivate vanilla on St. Lucia was to find a suitable support for the vines. Although annatto was rather satisfactory on land which was not too rich, the physic nut, calabash, hog plum and immortelle were difficult to keep under control in an extended cultivation. Old Liberian coffee trees lopped at a height of six feet were found to be best for support.

About 1900 the Agriculture Department of St. Vincent imported a number of vanilla plants from the Seychelles Islands and distributed them in the island. It was found that the tree fern (*Cyathea arborea*) was a good support for the vines.

Central and South America. Botanists familiar with the agriculture of Central and South America inform the author that, although vanilla is grown to some extent as a dooryard plant for domestic consumption, no commercial plantings as such exist in these regions.

In Guatemala the Indians of Alta Verapaz are said to collect wild vanilla in the woods along Río Polochic and in the forests northwest of Cobán (32). In 1943 the United States imported 18 pounds of cured vanilla beans from Guatemala.

Although no extensive commercial plantings exist in South America, it is of interest that in 1941 Brazil exported 9,652 pounds of cured vanilla beans to the United States. Until then Brazil had never sent more than 1,000 pounds of vanilla beans in any one year to the United States.

French Oceania

Tahiti. All of the vanilla beans exported from French Oceania are grown

in the Society Islands, of which the island of Tahiti is the largest single growing area. The acreage devoted to vanilla cultivation fluctuates with price increase and decrease.

Vanilla plants are cultivated principally on the sides of the islands where there is the most rain. The plantations usually are in small and irregular plots either on the narrow coastal plain or in the valleys of the lower hills. The work generally is carried on as a family industry, since it can be shared by all members of the family, including the children. The beans are grown principally by the Polynesian natives, but the drying and curing processes are carried on almost entirely by Chinese who buy the beans from the producers. Only persons holding licenses from the Government are allowed to buy and cure beans.

The vanilla industry is under rigid Government control. All the processes, from the time of picking the beans until they are packed for export, are controlled by law. The Government's agents fix the dates of harvesting and sale, inspect the quality of the beans presented for sale and control the weighing of the green beans sold, as well as the prices paid to the growers. A law exists prohibiting harvest for sale, transportation,

FIG. 18 (*Left*). Totonacan Indian girl in a vanillery. Papantla, Veracruz, Mexico.
FIG. 19 (*Right*). Totonacan Indian woman in holiday dress. Papantla, Veracruz, Mexico.

selling and preparing of vanilla beans which have not reached maturity. Inspectors visit the plantations to approve of the beans which may be gathered. If immature when gathered, the beans are seized by the authorities.

Green beans that have reached maturity may be sold to those engaged in drying and curing them only at sales which are held in the various districts after announcement by the Government's agents. The Government periodically fixes the prices to be paid to the producers so that there is now very little leeway for speculation. Strict regulations exist for the curing and processing of the beans. Government inspectors check the finished product and grade them according to the length of the bean. These grades are known as A, B, C, D and E, and are as follows:

Category	Color of label	Quality	Length of beans (centimeters)
A	Blue	Extra	At least 20
B	Pink	First	At least 18
C	White	Second	At least 14
D	Yellow	Third	Less than 14
E	Green	Inferior	Any length, thin, split or recured beans

In each case, except category E, the letter is followed by "1" to indicate perfect beans, or by "2" to indicate split beans of that quality.

The flowering, growing and harvesting season extends from about July to April. Pollination of the flowers, which is done mostly by children and women, begins in July and August, and there is a small crop harvested in December and January, the length of time and the amount of the crop depending on the amount of rain and sunshine. The main harvest is in February and March, ending in April. Drying of the beans ends in July and August, and most of the crop is sold shortly after the drying processes are finished. However, especially where there is an advanced market, driers may hold their dried beans many months, packed in tins.

The beans are cured by processes regarded as secret in certain respects. However, the principal part is careful daily handling of the beans during the three months drying and curing period. They are spread out on blankets on drying platforms while the weather is sunny and are taken inside at night or in rainy weather. Thus there are alternating periods of sweating and drying. Among other details the law provides that during the drying processes the beans shall not be exposed within 30 meters of a highway, and the wooden platform must be at least 70 centimeters above ground. The great amount of repetition and patience required is the work of the Chinese women. When ready for export, the beans are placed in paraffin paper-lined tin containers which weigh about 40 kilograms when filled.

During a ten-year period, from 1936 to 1945, an annual average of 133 metric tons of vanilla beans was exported from French Oceania. The smallest exports were 94 tons in 1936 and 65 tons in 1942; the largest were 206 tons in 1939 and 214 tons in 1941. In 1945, 102 metric tons, valued at $472,390 were exported from Tahiti, of which more than two-thirds went to the United States and about one-fourth to Australia. The largest and most valuable shipment was during 1941 when 214 metric tons, valued at $1,401,977 were shipped, largely to the United States whose normal source of supply was cut off by the war.

Australasia

Indonesia. Until about 1948, when exports completely ceased, Indonesia normally supplied about 1.5 percent of the world's requirements for vanilla beans. These were produced mainly in Garoet, in the highlands of West Java, in Kedoe and in the neighborhood of the city of Magelang in Middle Java (36). Vanilla was also grown to some extent in Peka-

FIG. 20 (*Upper*). Removing the stems, or "pezones", from green vanilla beans. Mexico.
FIG. 21 (*Lower*). Wrapping green vanilla beans in burlap sheeting and in fiber mats to form bundles, or "maletas". Mexico.

longan. Today vanilla production for export is negligible in Indonesia. The 1939–1941 average export was only 24 metric tons, most of which went to the United States.

Although quantity instead of quality was usually most desired in Java, the aroma of the beans produced was excellent, being superior to most beans produced elsewhere, and the vanillin content was the highest produced anywhere. According to Hoover (36), the vanillin content in Javanese beans tested ranged from 2.7% to 7.9%, with an average of 6.9%. Similar to many other localities where vanilla is grown, the Chinese cured the beans in Indonesia.

Australia. Vanilla was first introduced into the agricultural belt of Queensland some time before 1883. Its exploitation there, however, appears to have never been undertaken. The vine flowers in Queensland between September and November (16).

South Pacific

Hawaii. The vanilla plant was introduced into Hawaii long before 1900 direct from Mexico as well as from Tahiti, Samoa and Fiji. Although it does very well in the islands, its commercial exploitation has never been seriously attempted.

In 1903 the Hawaii Agricultural Experiment Station published a Bulletin in which was given a summation of what was known concerning vanilla cultivation in Hawaii. The following low-growing trees were recommended for use as vanilla supports: *Spondias lutea* (hog plum), *Erythrina lithosperma* (coral tree), *Crescentia* sp. (calabash tree), *Bauhinia tomentosa* (St. Thomas' tree).

Horticulture

General. The horticultural technique of growing vanilla is essentially the same wherever the plant is cultivated. The usual procedure is to select a suitable location, clear the land of all trees and shrubs except such as may be desirable supports for the vanilla plants to climb upon, prepare the soil, plant or erect mechanical supports for the plants to grow upon, plant shade trees and arrange a wind-break if necessary, obtain and plant the vanilla cuttings, train the plants over the supports used, keep the vines and living supports properly trimmed, watch for parasites and destructive diseases, see that the flowers are correctly pollinated at the right time, select and retain only the desired number of fruits to be allowed to mature, and finally harvest the crop which then has to be cured. A great amount of individual attention has to be given the plants. Consequently this will limit the size of the plantation which can be maintained at a highly productive and profitable level. Since vanilla is a crop that requires constant attention, everything possible should be done to facilitate the work. If the plantation is at the start planned and set out in an orderly manner, many unnecessary future expenses, as well as loss of time and labor, will be avoided.

In planning and establishing a plantation, factors additional to those enumerated above have to be considered. Foremost of these is selection of the geographic location. The plantation, of necessity, should be located in a region where a sufficient supply of cheap and intelligent labor is available because vanilla cultivation is an expensive operation at best. For this reason as well as for climatic considerations, the largest vanilla plantations have been developed in the eastern hemisphere in comparatively isolated places with a large native population. Lack of abundant cheap labor in tropical America, plus the fact that manual work is distasteful to or is considered beneath the dignity of many Latin Americans, has been a major deterrent to the establishment of vanilla, as well as certain other tropical crops, on a large plantation basis in this hemi-

FIG. 22 (*Upper*). Carrying the bundles of vanilla beans into the oven, or "calorifico" Mexico.

FIG. 23 (*Lower*). Sorting the partially cured vanilla beans. Mexico.

sphere. Most of the commercial vanilla produced in tropical America is grown by small independent "farmers" whose family, with possibly a few helpers, does all the work. Much vanilla is still gathered in the wild state.

Climate. In nature *V. planifolia* is commonly found climbing on trees in swamps, wet thickets and mixed forests in low country. It thrives best between the latitudes of 10° and 20° north and south, from sea level up to about 2,000 feet altitude and may even be found at 3,500 feet in Mexico. To flourish and be most productive, the plant requires a hot, moist, tropical climate with frequent but not excessive rains. Arid conditions and violent winds are detrimental to the plant. Like so many other spices, vanilla is most successfully grown on islands or in littoral regions having an island climate, and with the exception of those in Mexico, all of the larger plantings are on islands. A climate like that in southeastern Mexico, Madagascar, the Mascarene and Seychelles Islands, the West Indies, Tahiti and Fiji has proved to be ideal for the cultivation of vanilla. In these regions the temperature varies from about 70° to 90° Fahrenheit, with an average around 80°. The annual rainfall is 80 to 100 inches and is more or less evenly distributed throughout the year, with the atmospheric humidity always high. The ideal situation concerning precipitation is to have even distribution of rainfall through ten months of the year for continuous luxuriant growth of the plants and production of large fruits, with the remaining two months relatively dry so as to check vegetative growth and bring the vines into flower. Regularity of the proper climate is a most important point to be considered in the cultivation of vanilla, since temperature, humidity and various other ecological factors are thought to affect the quality of vanilla—its aroma and potency.

Location and Soil. If climatic conditions are suitable for growing vanilla, other factors which must be considered in developing a vanillery are type of terrain and soil. Level land which allows stagnation of water about the vanilla roots should be avoided. Likewise too steep a site should not be selected, since erosion may seriously affect the plants, and such a location will also add to the difficulty of attending to the plants. If the only available land slopes steeply, it should be terraced before the vanillery is planted. The ideal site, as noted above, is a gently sloping hill which allows adequate but not excessive drainage, permits maintenance of a leaf mulch at all seasons and will not interfere with cultivation of the vanillery. Any soil which is light, porous and friable, easily penetrated by the roots of the plant and abundantly supplied with decaying vegetable matter appears to be suitable for vanilla.

Since the roots of vanilla are mostly confined to the surface or humus layer, it is good practice to maintain a thick layer of humus. In a test McClelland (46) found that root development was 85% greater in leafmold than in soil. Also, the new vine growth was found to be considerably greater in leafmold than in soil. This emphasizes the necessity of keeping the vines continually supplied with a heavy vegetable mulch. In clearing the site, all bulky debris should be chopped up and left to decay. This should not be burned over. As is the case with all orchids, animal manures are harmful and should not be used, and, since the different vegetative organs of vanilla have been found to contain an exceptional amount of potash and lime, these chemicals should be present (20). The practice of adding burnt earth, lime and vegetable debris to the soil supplements to some extent these chemicals which may already be present. To help

FIG. 24 (*Upper*). Vanilla beans spread out in sun. Gutiérrez Zamora, Veracruz, Mexico.
FIG. 25 (*Lower*). Curios made from cured vanilla beans. Mexico.

prevent erosion and avoid exposing the vanilla roots to the sun and elements, excessive weeding should not, in most cases, be encouraged. Weeds are also an annual source of mulch for the plantation.

Supports. There is not complete agreement among growers as to which is the best support for vanilla—living trees, trellises, lattice-work, posts and wire or bars.

Posts are subject to decay and to the

ravages of termites, necessitating their being replaced at frequent intervals. In the case of wire or bar supports, the tender succulent vines may be easily broken over so thin a support, especially in a strong wind. Where supports other than small trees are used, it is always necessary to supply some form of partial shade for the vanilla plants. This is usually accomplished by planting tall widely spaced trees or banana plants.

Although the type of support depends somewhat on the region where the vanillery is established, the most satisfactory supports are unquestionably small trees. Selection of the tree to be used depends largely on local conditions. In general, however, small-leaved species which permit checkered sunlight to filter through are considered most desirable. Most growers prefer species which grow rapidly in full sunlight and which produce branches sufficiently low (from five to seven feet from the ground) for the vines to hang within easy reach of the workers. The tree should be strong enough to support the vanilla vine in a strong wind and should never become entirely defoliated. It should also be possible to propagate it from large cuttings so that the young tree will grow rapidly from the beginning. If possible, the trees should be planted a year or more before the vanilla cuttings are set out so that they will have had sufficient time to produce adequate support and shelter for the more rapidly growing vines.

The physic nut (*Jatropha curcas* L.), a common and widespread small tree which may be propagated from cuttings, is used extensively as a support. It also grows rapidly from seeds. In the Seychelles Islands, *Pandanus hornei* Balf. f. and several species of fig (*Ficus* spp.) are commonly used. Some planters in the Seychelles make the soil do double duty by growing vanilla vines on coffee trees. In Mexico the calabash (*Crescentia cujete* L.) and the coral tree (*Erythrina* sp.) are frequently used. The croton-oil plant (*Croton tiglium* L.) is used by some growers and is said to withstands winds of hurricane velocity. According to Ridley (54), in the Singapore Botanic Gardens vanilla was successfully grown on the African oil palm (*Elaeis guineensis* Jacq.). This being the case, it may be possible to grow these two tropical crops together, since their cultural requirements are somewhat similar.

In Puerto Rico bucare or immortelle (*Erythrina corallodendron* L.), and the coral-tree, or dwarf bucare (*E. berteroana* Urban), are well adapted for this purpose and have been widely used. In regard to the use of these trees in Puerto Rico, Medina (1943) found that:

> " When vanilla was grown on bucare supports under existing shade it produced more root germination, less seed-piece rotting, and more vegetative growth than when grown on the same kind of support trees on cleared land. The differences between the two groups of vines were considerable. The vines under existing shade were of a dark-green color characteristic of healthy normal plants as compared to the yellowish color of the vines grown on cleared land. Because of the nature of dwarf bucare to shed its leaves during the dry season, at the time when the vanilla plant needs shade, it would be preferable to use this support, where needed, only under natural or existing shade ".

Bauhinia purpurea L. and the anatto-tree (*Bixa orellana* L.) have been frequently used for supports. Some other trees used in various regions for vanilla supports are the horse-radish tree (*Moringa oleifera* Lam.), common screwpine (*Pandanus utilis* Bory), *Dracaena marginata* Lam., dragon's blood (*D. draco* L.), yellow mombin (*Spondias mombin* L.), hog plum (*Spondias* spp.), Liberian coffee (*Coffea liberica* Bull), coral-tree (*Erythrina variegata* Stickm.), madura (*Gliricidia sepium* (Jacq.) Kunth), lebbeck-tree (*Albizzia lebbeck* (L.) Benth.), horsetail tree (*Casuarina equisetifolia* Stickm.), avocado (*Persea americana* Mill.), tree fern (*Cyathea arborea* (L.) Smith), India rubber tree (*Ficus elastica*

FIG. 26 (*Upper*). Vanilla store room. The beans are kept here for observation after the curing process has been completed. Mexico.

FIG. 27 (*Lower*). Tying the cured and sorted beans into bundles. Mexico.

Roxb.), cotton tree (*Bombax malabaricum* DC.), mango (*Mangifera indica* L.), padouk (*Pterocarpus indicus* Willd.), *Lagerstroemia floribuna* Jack, jackfruit (*Artocarpus integra* (Thunb.) Skeels), loquat (*Eriobotrya japonica* (Thunb.) Lindl.), immortelle, cassava (*Manihot esculenta* Crantz) and arborescent species of hibiscus. The use of leguminous trees is advisable in that they help to improve the soil, especially if the land has been depleted by some previous crop.

It is of interest that in Madagascar *Casuarina equisetifolia* is now being used almost exclusively for vanilla supports. As shown by the illustrations, it makes a very neat and practicable plantation that gives easy access to the vanilla plants. *Jatropha curcas* was the support formerly used extensively in Madagascar.

Although the supporting trees usually provide sufficient protection from sun and wind, they are often inadequate for these purposes before the vines become mature. Tall, quick growing, wide spreading varieties of banana are commonly used to provide shade. In Mexico maize is often grown to shade the young vines. The vines and leaves are succulent and heavy, and if exposed directly to violent winds they are often badly damaged. If planted on an open hill or along the coast in a region susceptible to strong winds, a wind-break of some kind should be constructed or planted on the windward side. According to Ridley (54), red hibiscus has been recommended as a hedge for this protection. Any strong, thickly branched, wind-resistant shrub or small tree should be suitable for this purpose.

Propagation. Although vanilla can be grown from seeds, it is always propagated on plantations by means of cuttings. Various lengths of cuttings are used, the length having a decided influence on the development of the vine. In all cases the cuttings should be taken from vigorous healthy plants. In Mexico it is a common practice to use cuttings one foot in length, but cuttings three or four feet long are often employed. In some regions cuttings of six to 12 feet are set out so that the free ends may hang over the supports. If possible, long cuttings with 12 to 24 internodes should be used. Longer cuttings, if planted at the beginning of the rainy season, maintain a continued growth and bear flowers and fruits in one or two years. Short cuttings do not bear flowers and fruits until the third or fourth year. In the Seychelles Islands, during good growing weather—warm, still and moist—growth is rapid and some plants have been observed to grow as much as an inch a day (33). Experiments have shown that growth made by the shorter cuttings is greater in proportion to that of the longer cuttings. McClelland (46) found that in a 12-months period cuttings with two internodes grew 4.7 feet; with four internodes, 7.7 feet; with eight internodes, 10.7 feet; and with 12 internodes, 16.7 feet. Nevertheless, since the longer cuttings come into bearing much sooner than do the shorter ones, it is more economical and profitable, when material is available, to plant long cuttings.

After the surface of the ground has been leveled around the base of the support and a heavy application of vegetable mulch has been added, several nodes of the cuttings are covered by soil or leafmold at the base of the support. At least two nodes are left above ground, and this portion is trained to the support by being tied in several places to prevent swinging. If the free end is longer it is hung over the supporting branches and tied. Within several weeks the vine lengthens and sends out adventitious aerial roots which cling to the support. If necessary, cuttings may be started in a nursery and removed to the plantation. It is best, however, to start them in the plantations so as to avoid the possibility

FIG. 28. Mexican vanilla. Top, bundle of cured beans; note neatness and glossiness; left center, cured beans; right center, green beans.

of disturbing the roots when the plants are moved. According to McClelland (46), it seems to make little difference whether the cuttings are planted immediately or allowed to wilt 12 or 15 days. Sometimes the covered portion of the vine will rot away or become diseased, especially the injured basal tip. It has been observed that if the leaves are left on the cuttings to avoid injury by removal and the basal tip of the vine is left exposed to the air to heal over, the cutting usually escapes rot and other diseases. In some regions, as Dominica, the vine is merely laid on the surface of the soil and lightly covered with wilted grass after having been secured with two crotched pegs (46). It is advisable to use this method if rotting is prevalent in the plantation.

Planting. When originally developed as a plantation crop, vanilla plants were grown close together with the plants greatly entangled. This intensive culture produced enormous crops and was widely practiced until fungus diseases attacked the vanilleries in Réunion and other parts of the world. With the vines entwined as they were, it was a hopeless task to extricate the diseased plants from the healthy ones, and many vanilleries were completely wiped out or the plants devitalized to such an extent that they were essentially worthless. Although the yield is less and the cost of maintenance is more per acre, the usual practice today is to place the supports or supporting trees about nine feet apart and to grow only one vanilla plant upon each support. In this method there are only 537 vines to the acre, and a diseased plant may be easily removed from the vanillery without disturbing the healthy plants. Also, the plantation is easily worked when the plants are grown so far apart. Other methods are to grow the vines five feet apart in rows ten feet apart, giving 871 vines to the acre, or four feet apart in rows eight feet apart, giving 1,361 vines to the acre (46). These closer plantings give a larger return, but the close spacing of the plants is inconvenient for the workers and the plants are more susceptible to contagious diseases.

In nature vanilla grows in forests or shrubby land where it has filtered light or partial shade and a support upon which to climb. These conditions should be simulated in the vanillery for best results. However, instead of allowing the vines to grow to great length as they do in the wild state, they must be trained to grow within easy reach of the workers so that the flowers may be pollinated, the vines pruned and the fruits harvested. Various experiments have shown that vanilla plants grown under light shade are more healthy and produce a larger mass of sturdy vines than those grown in full sunlight or heavy shade. Heavily shaded vines are typically etiolated and spindly, whereas those grown in direct sunlight are yellowish and often burned.

Maintenance. Once established, a plantation has to be given constant attention. It should be gone over at least every other week so as to train the vines to grow at a convenient level, prune the growing vines and tree supports, watch for diseased plants and parasites, and to keep a mulch on the surface of the ground, especially over the roots of the plants. Cultivation of the ground is not feasible, since the roots grow at or near the surface and any disturbance of the soil would disturb them. As long as the vine can climb upwards it will not flower. Hence the tip of the vine is cut off nine or ten months before the flowering season. The blossoms are produced in the axils of the leaves on long hanging branches. When the plants are in flower they need daily attention. The flowers have to be pollinated and the stalk of the inflorescence must be clipped just back of the remaining buds, or the buds

themselves should be removed after the desired number of pods are set on each inflorescence. This prevents loss of the plant's vitality in the production of useless blossoms, avoids pollination of too many blossoms and saves the pollinator from having to examine superfluous flowers. All undesirable pods should also be removed. After flowering and fruiting, the old stems should be trimmed away. These will be replaced the following year with new and more productive stems. According to Ridley (54), heavy pruning of young stems is very productive, but it shortens the productive life of the plant to two or three years. After pruning, shoots will appear farther back, and these are left for the next year's crop.

The vines are said to reach their maximum production about the seventh or eighth year and may, if given proper care, continue to produce for several years more. One author gives 40 years as the maximum productive life of the vanilla plant, but this seems unlikely. In Mexico, at the end of three years after planting, a small crop is gathered, and for four or five years the vines continue to increase in size and productivity. At the end of nine or ten years the vines have lost their commercial value and are abandoned.

To prolong the life of the vines, some growers divide their holdings into four equal parts and pollinate the flowers in only one section each year. This method gives smaller returns at first, but a constant yield is maintained over a number of years because of the three years rest that each vine has between each crop. This rest period also tends to keep the vines in a vigorous condition and makes them more resistant to diseases.

FIG. 29. Madagascar vanilla. Bundle of cured beans; note vanillin crystals ("givre").

Pollination. Except in Mexico and other areas where the species is indigenous, all beans of *V. planifolia* are obtained by means of hand-pollination. In the regions where it is indigenous, *V. planifolia* is said to be pollinated by bees of the genus *Melipona* and also by humming-birds (54) which visit the fragrant flowers to obtain the honey secreted at the base of the lip. Insect-pollinated flowers, being cross-pollinated, produce seeds which will germinate and produce

plants, whereas flowers which are hand-pollinated, being self-pollinated, produce seeds which are sterile.

Since only a small percentage of beans set naturally, the Mexicans do not depend too much upon insect-pollination, but resort to hand-pollination. In this manner they are able to control the production of beans. "It is thought that families of French extraction living in Nautla introduced manual fertilization into Mexico about 1890 or 1895" (43).

Vanilla planifolia normally flowers but once a year, the flowers being produced in April and May in Mexico and as late as November in some regions. In Guadeloupe *V. pompona* flowers twice a year, in July and again in November and December. Some years the vanillon flowers almost constantly, being extremely vigorous.

Since blossoms last only a day, time is a most important factor in working a vanilla plantation. One to three flowers on the racemes open each day and remain open from early in the morning to late in the afternoon. The next morning the flowers are withered. A bright day following rain is considered the best time for pollinating, and a wet day or a period of extreme drought is not propitious. There is, however, no choice, for the flowers must be pollinated the day they open, regardless of the weather. To insure maximum yield of beans, the plantation should be gone over every day during the flowering season. In Mexico the thousands of flowers which open must be pollinated within a period of about 20 days. Only those flowers attached to the lower side of the rachis should be pollinated, since they will later hang perpendicularly toward the ground to form perfectly straight beans. Flowers attached to the upper side of the rachis should not be pollinated, since they will produce crooked beans of inferior quality and less value, which are also difficult to bundle and do not present an attractive appearance.

Hand-pollinating is a delicate procedure, although it is not a difficult operation and is rather easily learned by the most inexperienced worker. It is often the work of women and children who are quick with their hands. The only implement needed is a splinter of bamboo, a stem of stiff grass or a slender piece of wood the size and shape of a toothpick sharpened at both ends. Pollination is accomplished by lifting the thin flaplike rostellum that extends between the male (anther) and female (stigma) organs and pressing the pollen against the lower stigmatic surface.

An average worker may pollinate from 1,000 to 2,000 or rarely as many as 3,000 flowers a day (54). Records as to the actual number of flowers pollinated on the various plantations are not available, but about two million flowers are known to have been pollinated in one vanillery during one season (61). If pollination, with consequent fertilization, has been successfully achieved, the flowers will remain on the rachis; if not, the blossom drops off in two or three days. Consequently the worker can observe within a short time the number of pods set and can thus discontinue pollinating when the desired number have been obtained for a vine.

Fruiting. The number of fruits that are left to mature on individual plants varies in different regions. According to Ridley (54), "A good strong vanilla plant in full vigour should produce as many as 200 bunches or racemes of flowers at a time. Each raceme carries from 15 to 20 flowers, or even more . . . . Thus under good conditions a plant can give 4,000 flowers". He recommended that, in some cases, ten fruits be allowed to ripen on each raceme, but in the case of weaker plants only two or three should be allowed to ripen. If ten fruits were permitted to ripen on each of 200 racemes, the plant would produce 2,000 fruits! This seems incredible in view of the fact that a recent author advises that

an average cultivated plant will produce upwards of 25 perfect beans, whereas the wild vines produce only an average of three beans (45). In the Seychelles Islands about 30 beans are usually left to mature on each vine (33). According to the best authority, about 60 beans is the maximum number that should be expected from a cultivated plant. Ridley also stated that *V. planifolia* should be made to produce fewer fruits than *V. pompona*. If a plant has been forced to produce an excessive number of beans in one season, the beans produced the following season will be inferior and the vines left in a debilitated condition.

After fertilization takes place, the ovary elongates rapidly, growing as much as an inch a week, until the full length of the bean is attained in four to eight weeks. Depending upon the region where the plants are grown, it takes from three to ten months for the beans to become fully mature. According to Ridley (54), the fruit matures in about four months in the Straits Settlements and Cochin-China, six months in Réunion, and nine months in Trinidad.

Vanilla is usually picked from early November to late February in Mexico. However, because of the ever-present demand for the beans and also in order to

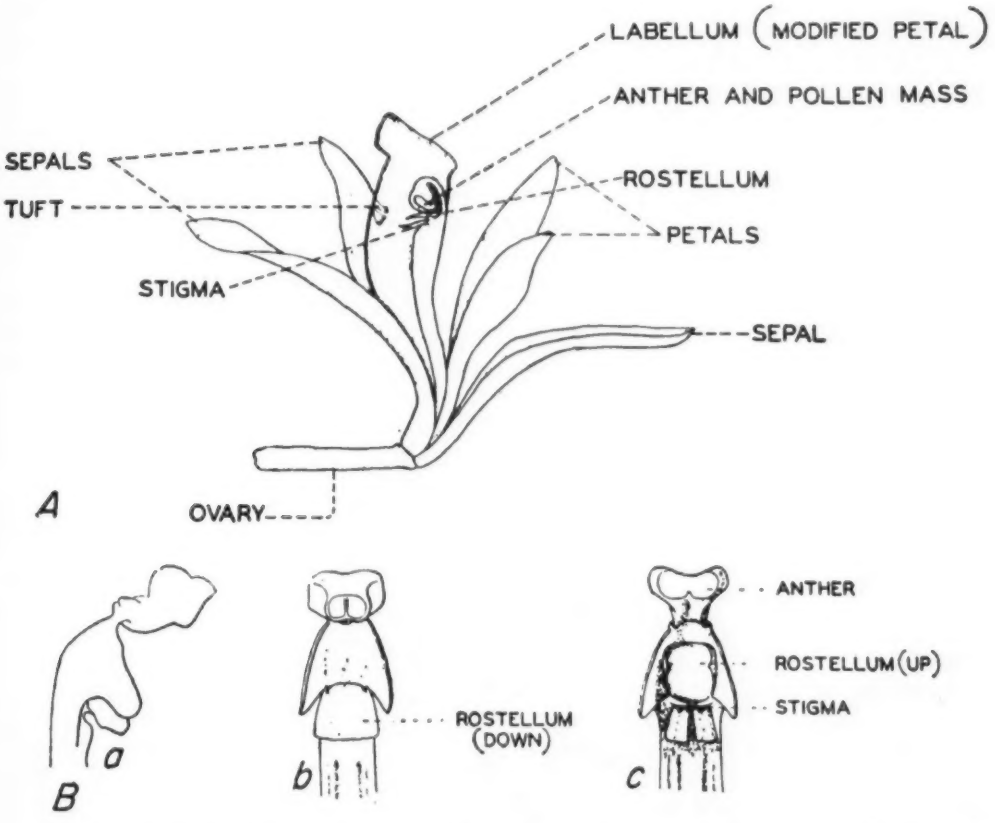
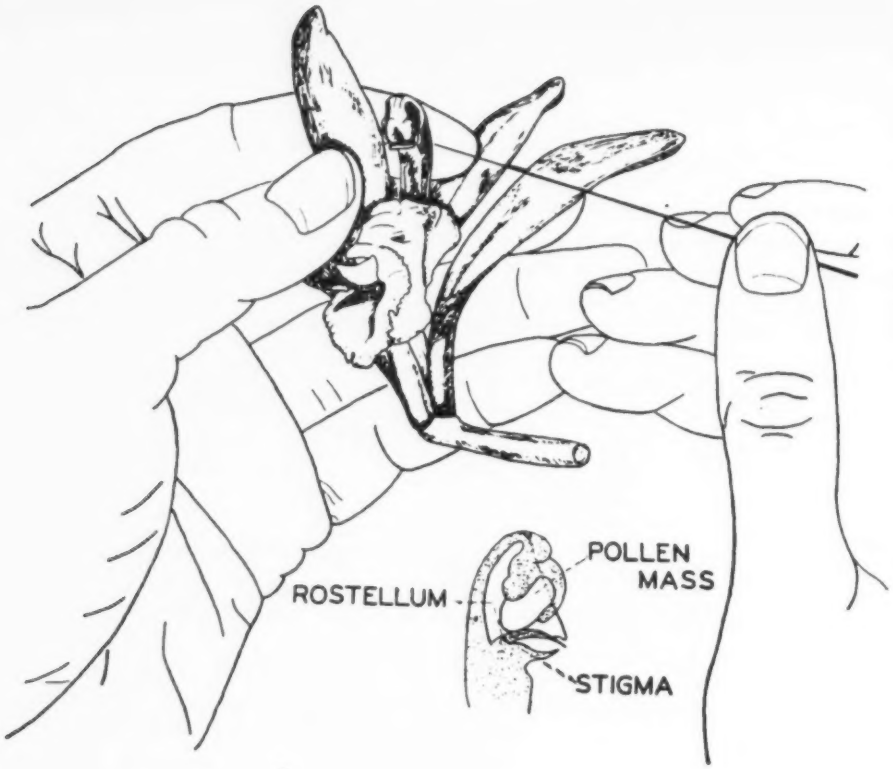
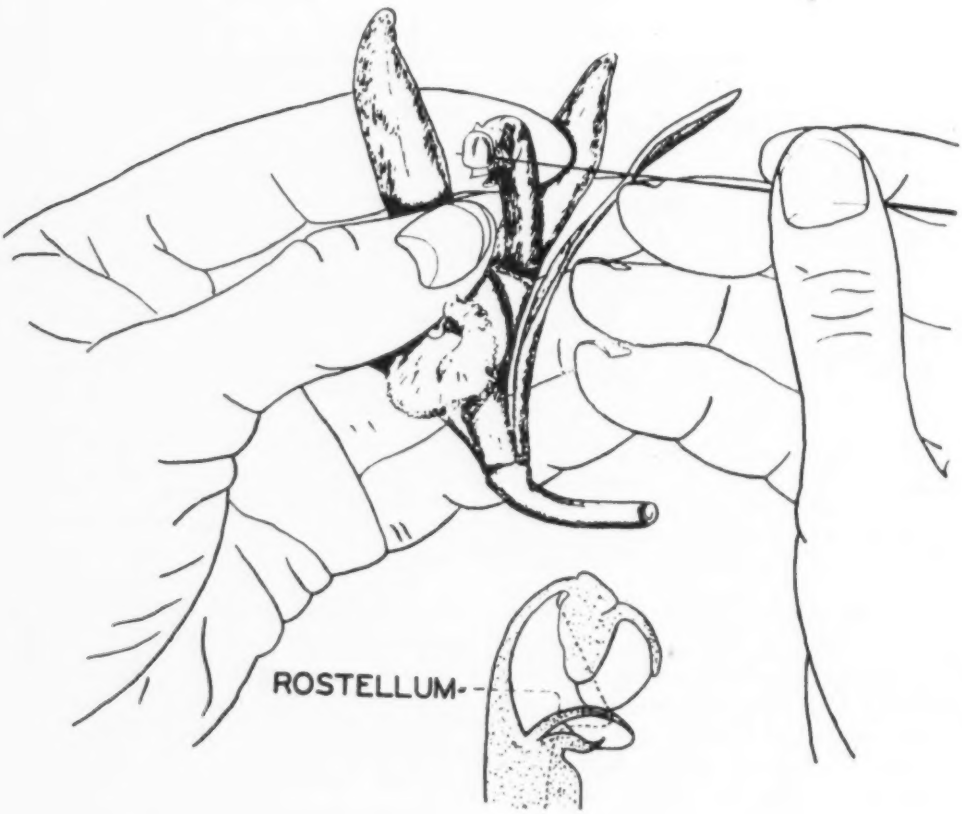


FIG. 30. A: Parts of the vanilla flower; the anther, rostellum and stigma are of chief interest in pollination. B: Column and rostellum in detail—*a*, side view of column; *b*, end of column with rostellum down, as normally; *c*, end of column with rostellum lifted, as must be achieved mechanically in hand pollination in order that the male organ (anther) can be pressed against the female organ (stigma).


POLLEN
MASS
ROSTELLUM
STIGMA


ROSTELLUM

circumvent theft of their crops (a general practice), some growers harvest their premature beans as early as October. This premature harvest is said to cause a loss of about one pound in every 1,000 beans (26), and, for example, the early harvest of 1940–41 is said to have caused a loss of at least 20% of cured vanilla (43). This economic evil persists and is growing in spite of the Mexican Government's efforts to curb it.

When mature and ready for harvesting, the beans are firm, thick, yellowish-green and quite odorless. An indication of ripening is a slight yellowing of the whole bean, more pronounced at the distal end. They must be gathered when fully mature but before they are too ripe. If gathered too soon they are deficient in aroma and are more subject to attack by a fungus. Long beans are more desirable than short ones, since they produce a superior extract, and an eight-inch bean weighs more than two six-inch beans or three five-inch beans (46). It takes 25 to 35 green beans to weigh one pound.

One excellent account of the ripening of the fruits of vanilla in nature tells us that (54):

> "If left on the plant, the pod begins to turn yellow at the lower end and gives off an odour of bitter almonds. The pod begins to split into two unequal valves, and a small quantity of dark balsamic oil, of a brown or red colour, is produced. Gradually the pod darkens in colour from brown to black. The epidermis softens and the real vanilla odour develops. The oil, which is called 'balsam of vanilla', then increases in quantity. This balsam is carefully collected by the planters in Peru and other parts of South America, but not sent to Europe. The pods, ripening slowly upwards from the tip, take about a month to fully ripen. Eventually, if left, the pods become dry and black and brittle, and are then scentless".

Diseases and Pests. Doubtless the most widespread and serious disease of vanilla is anthracnose, caused by *Calospora vanillae* Massée. The vegetative apex of the vine, the leaves and aerial roots are attacked. The fungus is thought to secrete a toxin in the soil that affects various parts of the plant when they come in contact with the soil. When plants that have been attacked are transplanted to uninfested soil they soon recover their vigor. This being the case, the vanillery should be established in soil that has never been used for vanilla culture. This disease has affected production of vanilla in the Mascarene, Comoro and Seychelles Islands, the West Indies, Tahiti and Colombia. Ridley (54) states that the disease was first noticed in the Seychelles Islands in 1887 when it was observed that hundreds of the finest and plumpest beans were wilted. They were observed to turn black at the end or in the middle, and to fall off in one or two days. It was found that if all dead or dying leaves of infected vanilla vines were destroyed by burning, the disease could be checked or even eradicated. Also, the presence of an excess of moisture in the leaves, prolonged rainy weather, insufficiently drained land and too much shade were all observed to favor development of the fungus. Overcrowding and excessive moisture were thus conditions to be avoided.

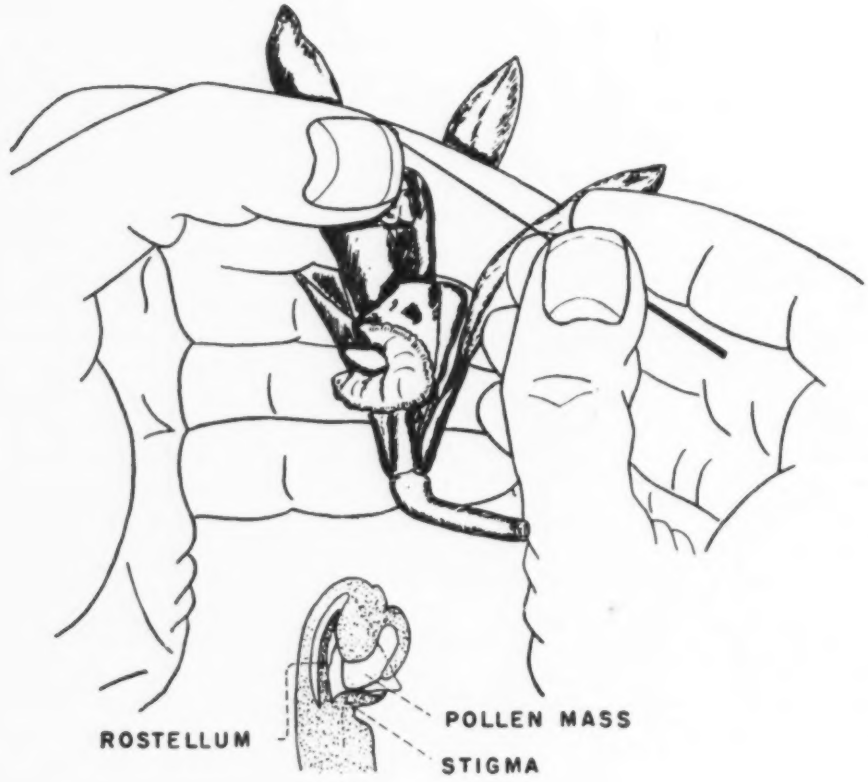
Various other species of fungi have been noted to attack different parts of the vanilla plant. In Tahiti, *Colleto-*

FIG. 31 (*Upper*). The four steps in hand pollination of vanilla flowers are shown in this and the next three figures.

First, the labellum (lip), a modified petal, is twisted down, leaving the column exposed. The flower is held in the left hand, and a bamboo stick or similar slender object is manipulated with the right hand.

FIG. 32 (*Lower*). *Second*, the bamboo stick is placed beneath the rostellum, or flap, that is lifted. See diagram of side view of column below hands.

ROSTELLUM


ROSTELLUM
POLLEN MASS
STIGMA

trichum vanillae Scalia has been found attacking the leaves (54), and in Madagascar, Puerto Rico and elsewhere *Fusarium batatis* Wollenw. var. *vanillae* Tucker causes root-rot. This latter disease is the factor that has most limited vanilla production in Puerto Rico. *Phytophthora parasitica* Dast. causes fruit-rot, and *Glomerella vanillae* (Zimm.) Petch attacks the roots. Other fungi parasitic on the leaves in various parts of the world are: *Vermicularia vanilla* Delacr. in Mauritius; *Gloeosporium vanillae* Cooke in Colombia, Mauritius and Ceylon; *Uredo scabies* Cooke in Colombia; *Guignardia traversi* (Cav.) Lindl. (41) and *Bacterium briosianum* Pavar. in botanical gardens in Italy; *Macrophoma vanillae* Averna and *Pestalozzia vanillae* Averna in Brazil; *Physalospora vanillae* Zimm. in Java; *Atichea vanillae* (Pat.) V. Hoeh. in Tahiti.

In his chapter on vanilla Ridley (54) reviewed quite thoroughly the diseases and pests known up to that time, 1912. A summary of the pests he discussed follows. *Trioza litseae* (Hemiptera, Psyllidae), the bug most destructive to vanilla, is recorded from Réunion. It attacks the buds and flowers, puncturing them and producing spots of decay. The emerald bug (*Nezaria smaragula* Fabr. (= *N. viridula* S.)), which is less destructive than *Trioza*, lays its eggs on the leaves and stalks of vanilla, and the insects when hatched suck the sap of the flower-buds and stalks. The most destructive weevil (*Perissoderes ruficollis* Waterh.) is found in Madagascar. A small lamellicorn beetle (*Hoplia retusa* Klug) and an ashy-gray weevil (*Cratopus punctum* Fabr.) bite holes in the flowers and often destroy the column. Two moth caterpillars have caused some damage. *Conchylia vanillana* (= *Phalonia*) attacks the young fruits and either causes them to dry up or produces irregular marks on the beans, which spoil them or lower their value as a product. *Plusia aurifera* Hb. (= *Autographa orichalcea* Fabr.) eats the buds of the plant. It is common in Réunion, Madagascar, continental Africa, Saint Helena, Teneriffe and southern Europe. The caterpillar of *Simplica inarcualis* Guen. is also supposed to attack vanilla on occasions.

Additional troublesome pests in Puerto Rico are snails (*Thelidomus lima* Fér.) and slugs (*Veronicalla kraussii* Ferussac) that attack the buds, leaves, shoots and immature fruits, and chickens scratching away the mulch, tearing the roots apart and exposing the roots to the drying atmosphere. Besides the above, a black weevil (*Diorymerellus* cf. *obliteratus* Champ.) causes injury to the tip of vanilla shoots, and a small leaf tyer (*Platynota rostrana* Walker), an aphis (*Cerataphis lataniae* (Boisd.)), an earwig (*Doru* sp.) and a woolly bear caterpillar (*Ecpantheria icasia* Cramer) cause minor damage to vanilla (21).

An important step toward combatting diseases of the vanilla plant, especially root rot prevalent in Puerto Rico, as well as increasing production and improving quality of the beans, was made by Lewis Knudson in 1950 when he, for the first time, successfully germinated seeds and produced seedlings of a hydrid vanilla developed in Puerto Rico. Knudson's discovery and techniques open the way for an entirely new line of research in the vanilla industry.

Harvesting, Curing and Grading

Harvesting. During the harvesting season the beans, which do not mature

FIG. 33 (*Upper*). *Third,* the rostellum is pushed to the back, while the left thumb is brought into position for the next step.

FIG. 34 (*Lower*). *Fourth,* with the rostellum up, the stamen is pressed downward with the left thumb until it smears the pollen upon the stigma below.

simultaneously, should be gathered every day. They must not be allowed to become fully ripened and should be picked before reaching the stage of dehiscing on the vine, since split beans are considered inferior to those which are not split. The beans are ready for cutting or picking when they become yellowish and develop a hard black tip. They may be easily removed unbroken from the vines by a sidewise pressure of the thumb placed at the base. Twisting should be avoided so as not to break the bean. If any portion of the vine comes away with the fruit, it should be cut away without injuring the base of the bean. On many plantations, instead of picking, the beans are cut from the vines with a sharp knife. After each day's gathering, for convenience in future sorting, the beans should be roughly divided into four classes: long, medium, short and split.

Curing. Various artificial methods are used in curing, or completing the ripening, of vanilla fruits, foremost of which are use of sun heat (Mexican process), of hot water (Bourbon process) and of stove heat. The beans may be killed also by freezing and by ethylene. Although they may differ somewhat in technique, all the methods have the same purpose of obtaining uniformly cured and unsplit beans as rapidly as possible. Curing is a process of alternately sweating and drying the pods until they have lost most of their moisture, as much as 80% being lost in curing Mexican beans. The curing process should begin within a week after harvest. In Mexico the process is carried out during the dry season which extends from November to May. The beans may be cured by the grower, but for the most part the green beans are brought by mule-train or men to trading centers and are sold direct to curer-exporters who not only are specialists in this work but have adequate facilities for curing operations. The curer's lot is full of problems. He buys the beans by weight, taking into consideration the odor, oil content and time of harvest, and, in turn, he sells his finished product by weight.

In Mexico, where traditionally the best vanilla is grown, the fruits are gathered and stored in sheds for a few days until they begin to shrivel. If the weather is fair they are spread on woolen blankets in the sun for a few hours until too hot to hold in the bare hands, after which the blanket is folded over them for the rest of the day. At the end of the day the bundles of beans are removed to blanket-lined, air-tight containers where they sweat all night. This process, which may take as much as two weeks or longer, is repeated until the beans turn a dark chocolate brown color. In cloudy weather the larger beans are wrapped in blankets, sprinkled with water and heated in an oven to 140° F. When the temperature has dropped to 113° F. the smaller beans are inserted (54). After 24 hours the small beans are removed, and 12 hours later the large ones are taken out. During this process the beans have sweated and acquired the desired rich brown color.

After the sweating process the beans are spread out on grass mats in the sun every day for two months or longer, after which they are spread in a shelter until sufficiently dry and ready for market. Care should be taken not to overexpose the beans to the sun, since this will cause them to be dry, less aromatic and of a reddish instead of deep brown color. In Mexico it takes from five to six months to bring the beans to a state of perfection. In Madagascar and Ré-

FIG. 35 (*Upper*). Examining vanilla beans in storage room at McCormick & Company, Baltimore, Maryland.

FIG. 36 (*Lower*). Chopping vanilla beans in preparation for making extract.

union not only is the above process used but often the sweating stage is preceded by one (15 to 20 seconds) or several shorter periods (3 to 4 seconds) of immersion in water heated to within a few degrees of the boiling point (about 190° F. or 86° C.). This, the Bourbon process, takes about three months to bring the beans to a state of perfection, and they are never so dry as the Mexican beans. The hot water process, by its very nature, results in an unequal treatment of all the beans and doubtless contributes to an inferior product than that from Mexico. Although the water is near the boiling point in which a bunch of beans is submerged, it is reasonable to assume that by the time it penetrates to the center of the bundle of cold beans it is quite cool.

Modifications of the above methods are practiced throughout the tropics wherever vanilla is grown. In recent years research has been undertaken by the Mexican Government to improve and hasten the slow and expensive methods of curing, but as yet no results have been published. Through conversations with individuals associated with large vanilla importing firms the writer is led to believe that within a few years the curing methods discussed here will be only of historic interest, since it appears that the curing of vanilla beans may soon be completed within a matter of hours.

The so-called Guiana process consists of placing the beans in ashes until they shrivel, after which they are rubbed with olive oil, tied at the lower end to prevent splitting and hung in the open air until dry; the Peruvian process includes dipping the beans in boiling water, after which they are tied at the lower end, dried in the open air for three weeks and then lightly rubbed with castor oil, after which they are bundled (54). A number of other such primitive processes are used in various regions.

The so-called "Potier's Process" should be appealing to the connoisseur. After having been soaked in rum for 20 or 30 days, the pods are exposed to the air for 36 to 48 hours, without becoming completely dry. They are then shipped in the rum in which they were first soaked. Simplicity is claimed for this method but it is expensive.

Grading. When properly cured and dried, vanilla beans are dark brown and supple enough to be twisted round the finger without rupturing. Before being packed they are usually smoothed and straightened by being drawn repeatedly through the fingers. This massaging helps to bring out some of the oil which exudes during fermentation and gives the beans their characteristic lustre. Some beans are said to be coated with mahogany oil to render them supple and to preserve them from insects (32). Usually the beans are covered with white needle-shaped crystals of vanillin, the presence of which is considered by some to be a criterion of high quality.

> "Apart from the attractive crystals on the outside, the main pocket-lens features of the vanilla pod lie inside. The pericarp or fruit-wall has about twenty conducting strands, and three dark lines marking the limits of the valves which normally open as only two, one single and flattish, the other double and curved in cross-section. The central cavity is packed with numerous small black seeds embedded in a gummy oleoresinous matrix which is secreted by three bands of fine hairs occupying the corners of the more or less triangular cavity. The seeds are developed in twelve rows, on three pairs of placentae, each placental ridge having two lateral rows of seeds. These structural details are rather difficult to distinguish in a dry pod, but a cross-section shows some indications of strands and placentae in the pericarp, and also the mass of seeds and secretions in the center" (61).

Vanilla beans are subject to attacks from mildew, especially if they are improperly cured and have not been sufficiently dried. Once the beans become permeated with the odor of mold, it is

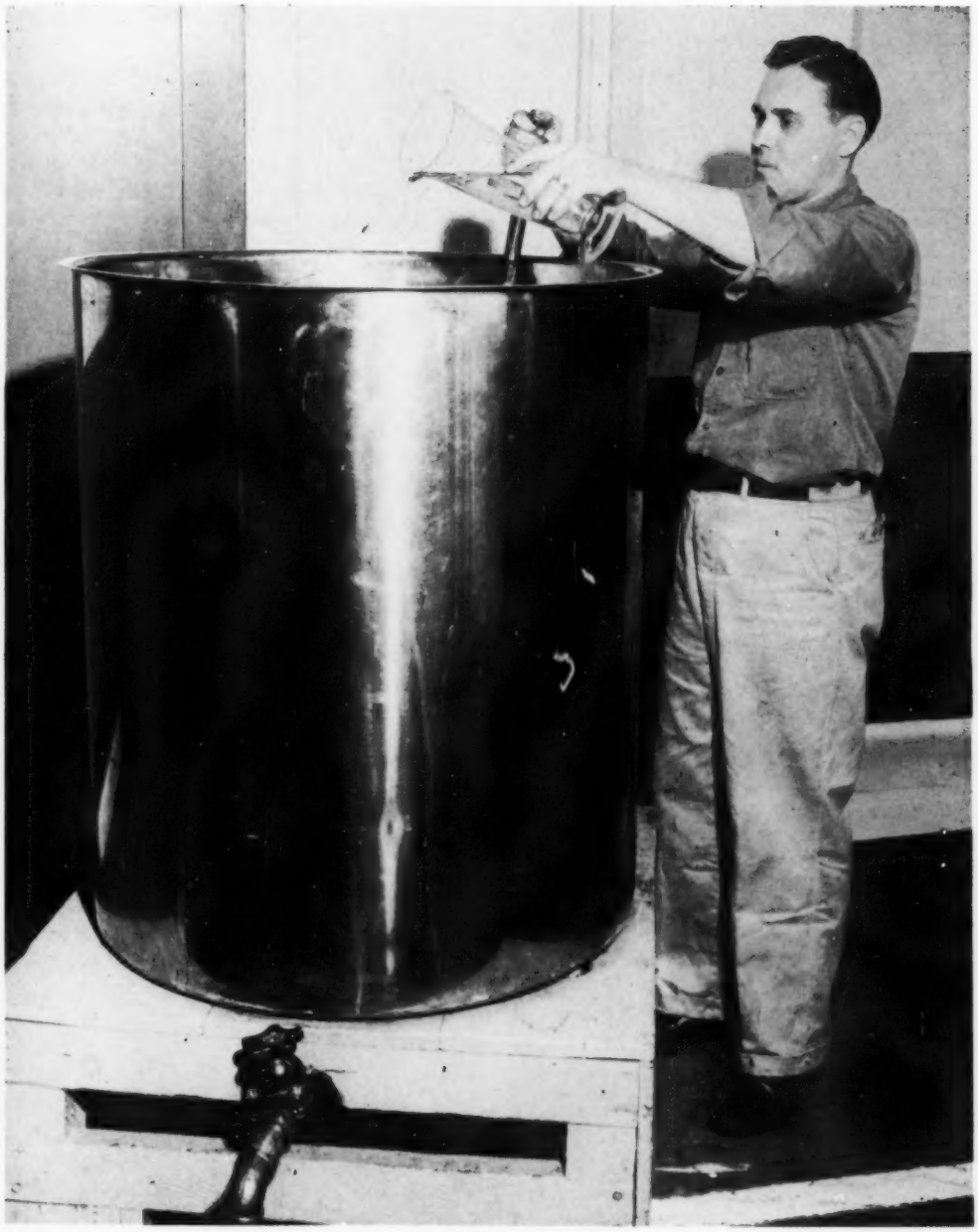


FIG. 37. Mixing tank, percolation process.

practically impossible to eliminate it and the value of the beans is much reduced. The moldy portion is cut away and the remainder of the beans, known as "cuts", is sold for perfuming soaps, etc. In Mexico these "cuts" normally range from 10 to 20 percent of the crop, but when the demand for vanilla is heavy, especially early in the season, and the prices are good, the number of "cuts"

increases (43). The time of curing is less and the packing for shipping easier than for whole first quality beans. Not all the "cuts", however, are the result of mildew. They also consist of beans of inferior quality. Those beans which have split during the curing process are also set apart to be sold as "splits".

Dealers in vanilla often try to remove the mildew by washing the beans in alcohol and rubbing them with glycerin, and try to prevent its reappearance by use of formaldehyde, but the moldy odor will persist. Beans with more than 36% moisture content are considered to be subject to molding (54). In the United States the Food and Drug Division forbids entry of vanilla beans cured with the help of salicylic acid, formaldehyde or mercury.

Vanilla beans are always marketable as long as they are well cured, of sound keeping qualities and possess a sweet flavor. They will keep indefinitely if properly cured and stored. The value of vanilla depends almost entirely upon the curing and packing of the beans. During the curing process the beans are continually under observation so that any which may be moldy or defective in any other way can be removed. The same intensive care is given to sorting and packing the fruits.

The beans are sorted into several classes, primarily as to quality and length, before being packed. The best are without defects, being oily, smooth, strongly aromatic and essentially black or very dark brown. Second class beans are somewhat defective in that they are over-dried, less aromatic, have a rough exterior and are somewhat reddish. Split beans, which have lost some of their perfume, comprise the third class.

Vanilla beans of commerce have been divided for convenience into five principal geographic types—Mexican, Bourbon, South American (including vanillon, West Indian vanilla and pompona), Tahiti and Java. Mexican beans come from Mexico only. Bourbon beans were originally from the Island of Réunion (Bourbon) only, but they now include all beans grown in Madagascar and the Mascarene, Comoro and Seychelles islands. The Bourbon crop was formerly handled almost entirely through France. South American beans are grown mainly in the French West Indies. Tahiti beans are an inferior vanilla grown in the French group of the Society Islands. The crops are large in Tahiti, but the beans are usually rank in flavor. Java beans are grown in Indonesia, the bulk of the crop formerly having been sent to the Netherlands.

"In Mexico five classes of vanilla are known. The best is *primera*, the pods of which are 24 cm. long and proportionally thick; the second are called *chica prima*, the pods being shorter and two counting as one; the third is *sacate;* the fourth, *vesacate*, and still smaller, and are gathered before they are ripe; the fifth quality is *basura*, with small, spotted, and much broken pods" (54). The sacate is said to be a large bean which grows abundantly along the roadsides in the warm regions of Mexico, where formerly its fruit was considered to be without commercial value (26). The Mexican beans are usually larger and darker than those produced elsewhere.

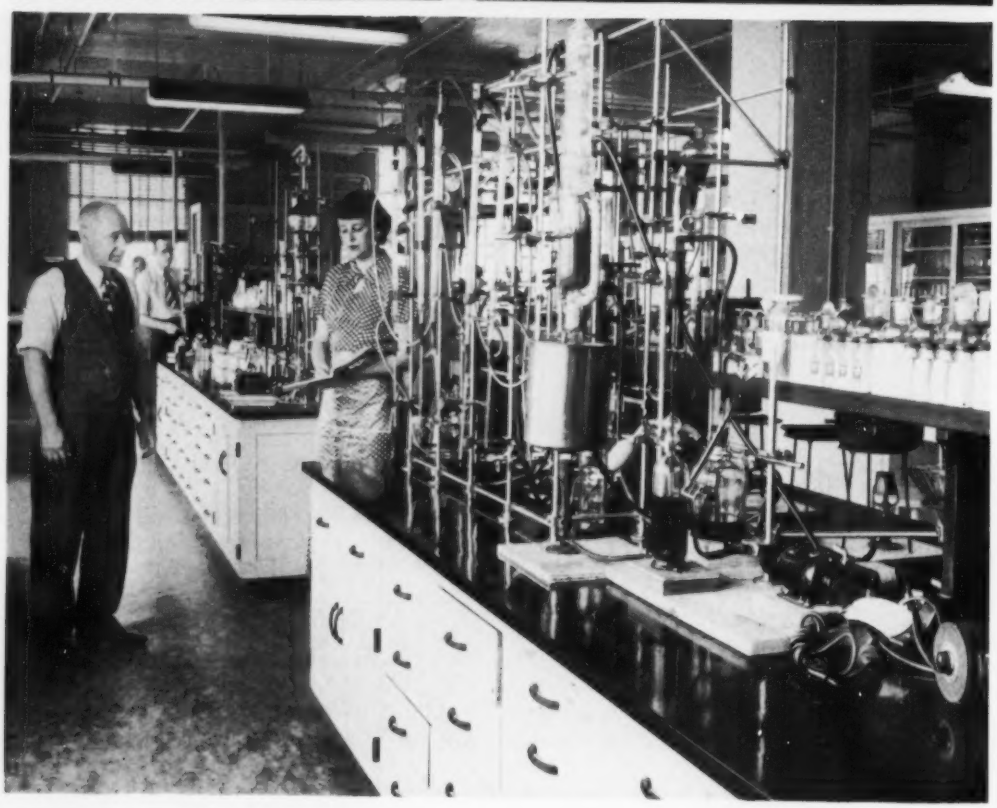
The above classification of Mexican vanilla beans was in force until rather recently when the following seven grades were instituted: *a*) Extra, *b*) Superior, *c*) Buena Superior, *d*) Buena, *e*) Mediana Buena, *f*) Mediana, *g*) Ordinaria. These range from beans of exceptional quality to the most inferior and "cuts", and are based largely on moisture content, varying from 20 to 40 percent.

After sorting, the beans are either sold in bulk or are tied in bundles of 50 to 90 each and packed in tin boxes containing as much as 85 pounds (54). After being soldered, three tins each are placed in

FIG. 38. Percolator for making vanilla extract.

wooden cases, preferably cedar, and are ready for shipment. When received by importers in the United States the beans are examined, and the tins are then placed in storage where an effort is made to maintain the temperature between 65° and 68° F. No attempt is made to control humidity.

The fruits of *V. pompona*, vanillon, are not mixed with those of *V. planifolia*



and are packed separately or sold in bulk.

In 1949 vanilla powder, consisting of old and unexportable beans pounded in a mortar, was exported from Madagascar in an attempt to determine whether a market for powdered vanilla could be found in the United States and France. This practice was abandoned, since the French did not approve of making vanilla powder for export, especially since it could be easily adulterated. Instead it was considered better to follow the Mexican practice of exporting "cuts", wherein inferior beans of all types, especially those of poor size or quality, are cut into pieces and sold at lower prices than the best grades.

Past and Present Uses: Economic Importance (World Trade)

Uses. Vanilla is today one of the world's most important flavoring materials. Since its early advent into Europe shortly after 1520, it has competed strongly and successfully with other spices in the world's markets, and as late as 1908 at least three times as much vanilla as all other flavoring materials was said to be consumed annually (46).

Vanilla beans, as mentioned above, were used by the ancient Aztecs of Mexico and Central America for flavoring chocolate long before the arrival of the Spanish conquerors. When first introduced into Europe, vanilla was used primarily as a flavoring for chocolate or as a tobacco perfume. Early explorers of tropical America, however, extolled its medicinal virtues, and vanilla soon became an important drug, its reputation as an aphrodisiac being widespread. Belief in the medicinal properties of vanilla was strong during the sixteenth century; as early as the beginning of the seventeenth century it was given a place in the German Pharmacopoeia, and in 1721 it had a place in the London Pharmacopoeia (61). Use of vanilla as a medicine waned during the latter part of the eighteenth century, and by the end of the nineteenth century, for all practical purposes, it was eliminated as a drug. It is still employed to some extent, however, in medicine mainly to flavor otherwise distasteful elixirs and certain medicinal solutions.

It is interesting to note that at the height of its exploitation as a drug, physicians propounded various theories concerning the supposed therapeutic effects of vanilla which today seem preposterous and ridiculous. One medicinal flora stated that:

> ". . . vanilla exercises a powerful action on the animal economy, and justifies the attributes of tonic, stimulant, and comforting, which are accorded it. The truly active and strong impression which it makes on the nervous system by its fragrant aroma, and on the stomach when taken internally, is rapidly and sympathetically transmitted to all the organs, the functions of which it more or less accelerates. Hence, when the system is lowered, vanilla facilitates digestion and nutrition, augments the cutaneous transpiration or the secretion of urine, and acts as a tonic in various other ways. It is recommended in cases of dyspepsia, melancholy, hypochondria, and chlorosis, where the digestive functions are sluggish or torpid" (32).

On the continent of Europe vanilla was also at one time used in hysteria, low fevers, impotency and rheumatism, and was thought to prevent sleep and "increase the energy of the muscular system". It was used by Spanish physicians in America to cure various maladies, being considered a strong stimulant and stomachic, and as an antidote to poison and to the bite of venomous animals (9).

In Mexico, home of the vanilla, very

FIG. 39 (*Upper*). Mixer and storage tanks.
FIG. 40 (*Lower*). Analytical Laboratory at McCormick & Company used in making vanilla extract.

few of the natives who work in the industry are said to taste vanilla because they have developed the impression that it possesses properties which cause it to act injuriously upon the nervous system (32). In fact, only a very small amount of the natural product is used in Mexico. Instead, artificial vanilla, which costs only a fraction of the price of pure vanilla, is imported for national consumption. This condition is doubtless, at least in part, the result of vanilla being a highly remunerative crop for export and not necessarily because of any antipathy to the bean.

Since vanilla beans display a fine brown color, they were at one time thought to be a possible source of dye. During the last century the Germans unsuccessfully experimented with the beans for this purpose.

Vanilla is by far the most popular flavor at the present time in the ice cream, baking and chocolate industries in the United States. It is chiefly used as a flavoring of chocolate, beverages, confections, cakes, custards, puddings and ice cream, and in the manufacture of soaps, perfumes and sachet powders. When added to the heavy oriental varieties of perfume, vanilla extract makes the odor more delicate. Vanilla is ordinarily used in the form of an extract from the beans. In the manufacture of chocolate, however, the beans are usually ground finely with sugar and included with the chocolate. One bean is considered sufficient to flavor 1½ pounds of chocolate. The bean is also sometimes used directly in the manufacture of ice cream and other confectionary. Some chefs still insist on using the bean itself in the food to be flavored instead of using the extract. Since vanilla essence is known to be more volatile at high temperatures, there is perhaps some justification for this rather expensive practice.

All consumers want a good perfume in their beans. Some want good appearance, as beans that are soft, fat, unctuous, long, of good color, with minimum spots. This is especially true of beans for the French market where the housewife buys the actual bean instead of an extract. Other buyers, as in the case of the Americans, consider appearance as secondary, since their purchases are mainly for extracts; dry beans, as those prepared in Mexico, are desired so as to avoid liquid content.

In recent years vanilla has been used in poison bait for such pests as fruitflies, grasshoppers and melon beetles.

Economic Importance (World Trade). Statistical data concerning vanilla are are not too satisfactory or reliable, whether they are concerned with the amount of vanilla grown throughout the world, consumed in situ or exported, or the proportions utilized in the manufacture of various products. The following information has been extracted from United States Department of Commerce reports and other sources.

The United States normally imports about four-fifths of its vanilla beans from sources outside the western hemisphere. Before the last war imports came principally from France and its colonies; today they come direct from Madagascar and other regions in the eastern hemisphere. In 1945 the United States imported more than one and a half million pounds of vanilla beans, valued at nearly nine million dollars. About two-thirds of these imports came from Madagascar and other French colonies. In recent years vanilla beans have been second only to coffee and tobacco in export value from Madagascar. In the same year, 1945, Mexico, the source of beans of best quality, provided more than 500,000 pounds. The United States annually consumes about 500 metric tons of vanilla beans and traditionally maintains stocks of about 300 tons.

In 1920 Cunningham (26) wrote:

TABLE I

UNITED STATES IMPORTS OF VANILLA BEANS (POUNDS): AVERAGE FOR 1935–1939 AND FROM 1940 TO 1951 [8]

Country of origin	Average 1935–39	1940	1941	1942	1943	1944	1945
Madagascar	193,113	493,992	87,593	372,468	368,316	231,467	1,176,384
Mexico	222,720	370,987	576,836	138,598	222,830	449,937	159,164
French Oceania	42,526	154,122	199,657	185,503	115,516	170,956	158,591
Indonesia	20,541	17,021	83,364	19,996	.....	.....	.....
British West Indies	4,289	8,406	9,939	13,744	23,945	43,015	58,976
French West Indies	16,581	23,491	31,526	24,344	7,452	.....	32,634
British East Africa *	.....	1,220	262	7,671	100	.....	.....
Seychelles Islands	.....	9,548	568	1,254	7,599	.....	.....
France *	493,776	213,200	18,701	.....	.....	.....	.....
Other	12,928	29,237	11,452	751	2,828	12,414	3,282
Total quantity	1,006,474	1,321,224	1,019,898	764,329	748,586	906,789	1,589,031
Value	$2,502,628	$4,913,133	$5,615,833	$4,605,719	$4,276,249	$5,119,908	$8,757,813

Country of origin	1946	1947	1948	1949	1950	1951
Madagascar	849,623	990,651	203,830	639,850	1,682,760	812,388
Mexico	150,215	320,913	663,124	332,432	279,760	237,928
French Oceania	192,562	163,793	112,535	95,735	162,798	90,929
Indonesia	1,242	33,898	8,325	23,564	89,875	85,040
British West Indies	49,934	14,687	30,680	54,987	27,493	27,314
French West Indies	20,768	10,556	4,152	13,504	44,865	12,243
British East Africa *	2,211	1,045	5,898	14,277	7,848	14,863
Seychelles Islands	.....	426	.....	3,924	9,016	.....
France *	.....	4,533	14,349	.....	.....	.....
Other	1,788	15,746	32,667	2,461	7,590	.....
Total quantity	1,268,343	1,556,248	1,075,560	1,180,734	2,312,005	1,280,705
Value	$7,169,986	$9,193,747	$5,123,614	$3,490,742	$6,448,802	$3,425,508

* Reshipment from other regions.

"Because of the fact that the United States buys most of the vanilla of Mexico the dollar is the basis of price, both for buying and selling. The price paid at the plantation varies from $2.50 to $3 per pound, while the price in Vera Cruz is about $3.50 per pound. The New York price is about $4.50 per pound, with duty paid. Mexico levies an export duty of 1 peso per kilo plus a surtax of 10 percent. These have been the ruling prices for 40 years".

However true the above may be, in recent years the price of vanilla beans remains in a state of flux, not only in Mexico but also in other regions. In 1900, Mexican beans sold for about $9.00 per pound (46), in 1939 they sold for approximately $4.00 per pound, and in 1950, about $5.00 per pound. Because of its overwhelming production of good quality beans, Madagascar and the United States market determine the price of this product during normal times. As much as $250.00 per pound is supposed to have been paid for vanilla beans at one time (32). There are so many factors which influence prices that they cannot be considered a true index of quality.

In 1942, Mallory et al. (43) wrote concerning Mexican beans: "In 1941, vanilla returned to its value in the days of the Spanish Conquest when it nearly equaled its weight in silver. In January 1941 it was $9.25 a pound; today it is $16". During the same year Madagascar beans, when obtainable, were selling at $13.00 and $14.00 per pound.

[8] Data from United States Department of Commerce.

Until 1947 Madagascar, including Comoro Islands and Nosy-Bé, exported a yearly average of around 400 metric tons of vanilla beans. The highest was in 1929 when 1,091 metric tons were exported; the lowest, being almost nil, was in 1942 as a result of the war. Direct purchases by the United States began in 1932. They reached their peak in 1946 when about 430 metric tons were exported to the United States. Direct shipments to the United States from Madagascar began in 1944 when ships were available.

In recent years, since 1945, Madagascar and Comoro Islands have exported the following amounts of vanilla beans: 1945, 486 metric tons (428 went to U.S.); 1946, 653 metric tons (430 went to U.S.); 1947, 485 metric tons (303 went to U.S.); 1948, 461 metric tons (24 went to U.S.); 1949, 585 metric tons (84 went to U.S.); 1950, 589 metric tons (about 300 went to U.S.).

Percolation of Extract[9]

To manufacture an extract from the whole cured vanilla bean, it is necessary to dissolve the flavoring substance in the bean in a suitable solvent, usually alcohol and water, and to separate this liquid extract from the spent bean residue. By law, 100 cc. of the finished alcoholic extract must contain the soluble material from at least ten gm. of beans[10].

Whole vanilla beans are chopped or cut into small fragments such as might pass through one-half or one-inch openings. The chopped beans are placed in a percolator in which a solution of alcohol and water is circulated continuously through the mass of chopped beans. Ordinarily at least 40% alcohol is used in order to avoid extracting certain gelatinous materials which would clog the percolators or later precipitate from the finished extract. Glycerin, an optional ingredient, can be added either during percolation or at a later stage. The beans may be completely and continuously immersed in the alcohol-water menstruum with provision for agitation of the mixture or circulation of the liquid, or the beans may be suspended in perforated trays, so that the solvent is permitted to drain out but is continuously recirculated by pumping or thermal convection.

Extraction is usually conducted at room temperature or at a temperature slightly elevated to perhaps 110 or 120 degrees Fahrenheit. Raising the temperature speeds up the rate of extraction, but it is felt by some manufacturers to produce an inferior extract. The extraction can be conducted in one step with almost all of the total final quantity of alcohol and water being brought into contact at one time with the chopped beans. Greater efficiency may be obtained by dividing the extraction process into steps and bringing fresh solvent into contact with the partially exhausted beans at each step. Countercurrent extraction methods have also been applied. Another procedure involves extraction followed by partial distillation, condensation and re-use of the solvent. However, unconcentrated extracts are usually produced by the simpler single step or stepwise percolation procedures first mentioned.

At the end of the extraction process the beans retain a considerable quantity of alcohol and water. This may be recovered for re-use by drainage, followed by washing with water, pressing, centrifuging or distillation.

To the extract so obtained can be added dextrose, sucrose or glycerin. These are intended to prevent precipitation of the substances extracted from the beans and to preserve or retain the

[9] Contributed by Richard L. Hall, Director of Research, McCormick & Company.

[10] Oddly enough, no designation regarding the quality of the beans to be used is specified in the pure food and drug law (Author).

flavor and aroma of the product. It is common practice to age the extract for some time before filtering and bottling it.

Substitutes and Miscellaneous Information

A number of related and unrelated plants have flowers, fruits or vegetative parts which emit the odor of vanilla. While some are of no apparent use, others have been utilized as a substitute for, or adulterant of, commercial vanilla. The long cylindrical pods of "chica vainilla", or little vanilla (*Selenipedium chica* Reichb. f.), are said to have been highly esteemed at one time by the inhabitants of the Isthmus of Panama. These pods were used for all purposes for which real vanilla is commonly employed. The Faham or Bourbon tea leaves of the Mascarene Islands from the orchid *Angraecum fragrans* Thou., and the dried leaves of *Orchis fusca* Jacq. of Eurasia are said to possess the odor of vanilla (32). The familiar fragrant ladies' tresses (*Spiranthes cernua* (L.) L. C. Rich. var. *odorata* (Nutt.) Correll) of the eastern and southern United States has flowers which are strongly fragrant of vanilla.

An attractive herb, popularly known as "vanilla-plant" (*Trilisa odoratissima* (Walt.) Cass.) and found on the coastal plain of the southeastern United States, at one time served as a vanilla substitute. The leaves contain a large amount of coumarin and were relied upon primarily as a flavoring agent for tobacco. They are still used to some extent for this purpose. The plant was extensively gathered, and, about 1875, one dealer at the trading center of Palatka, Florida, had an order to fill for 150,000 pounds (10). Although used to some extent in this country, a much larger quantity was shipped to Germany and France. The little orchid "herb vanilla" (*Nigritella angustifolia* Rich.) which grows in the mountains of Switzerland is said to derive its common name from the fact that on hot days it emits a powerful odor similar to that of vanilla (32). Common sweet clovers (*Melilotus* spp.), too, contain coumarin and have a slight odor of vanilla.

The most widely used vegetable substitute and most notorious adulterant of vanilla is tonka, or snuff bean (*Dipteryx odorata* (Aubl.) Willd.), the seed of a leguminous tree native to northern South America and Trinidad. Venezuela, Brazil and Trinidad are the chief exporters. The beans usually sell for 50 to 75 cents a pound and are chiefly sold in the United States, with a smaller market in Europe. They contain a high percentage of coumarin and are used mainly in the manufacture of tobacco and perfume; to a lesser extent in confections and the flavoring of liqueurs. Another tonka bean (*D. oppositifolia* Willd.) is also said to be used as a vanilla substitute. The vanilla-like odor of tonka is attributed to the large amount of coumarin present. This substance, if taken in too large a quantity, is said to produce poisonous effects, 30 to 60 grains being sufficient to cause nausea, depression and drowsiness (32).

Some little known and less common wild vanillas are also thought to be used as adulterants of the true vanilla of commerce. Vanillon (*V. pompona*) is the species commonly used for this purpose, but there are doubtless others. According to Small (61), manipulated vanilla beans which have been exhausted and redried or roasted are sometimes sprinkled with crystals of benzoic acid, which simulate those of vanillin, and are placed on the market. These benzoic acid crystals, however, do not yield the carmine-red color given by vanillin with phloroglucin and hydrochloric acid. Synthetic vanillin crystals are sometimes sprinkled over low grade or "treated" beans to improve their appearance. Heliotropine, cinnamic acid derivatives and various

perfumes are also said to be used as adulterants of vanilla. Perhaps the most common method of adulterating vanilla extract, and the most difficult to detect, is the use of fewer beans than the standard requirements. Although not used as a flavoring, the expressed juice of the fruits of a species identified as *V. claviculata*, native to the West Indies, is said to be applied to recent wounds and is called "liana à blessure" by the French in Santo Domingo (9).

The chief competitor of natural vanilla and the product which is commonly used to fortify the pure extract is synthetic vanillin, or artificial vanilla. Methyl vanillin and ethyl vanillin are also sometimes utilized. All of these are many times stronger than the natural extract but do not match it in quality. Ethyl vanillin is considered to be about three times as strong as methyl vanillin, and has a superior, stronger and more delicate odor which comes nearest to the peculiar aroma of Bourbon vanilla beans (37). Another material, vanillic acid ester of vanilla alcohol, is said to be at least twice as strong as vanillin and has been strongly advocated as a flavor (37), especially during times of national emergency when shortages of containers and transportation facilities necessitate reduction and concentration of all products so far as possible. A small amount of vanillic acid ester is equal in flavoring potency to a large bulk of natural vanilla extract and would, consequently, be more practical for overseas shipments.

These products, which cost only a fraction of what pure vanilla extract does, have not seriously affected vanilla culture, but have been an important factor in reducing the rather exhorbitant prices once paid for vanilla beans. Most vanilla beans grown today have a market before they are harvested. In fact, the total crop grown throughout the world is insufficient to satisfy the needs, and the steady demand for the natural flavoring would seem to warrant development of additional plantations, especially in Puerto Rico and other regions near to the United States.

German chemists were the first to place synthetic vanillin on the market. It was ". . . first produced in 1874 by Tiemann, through a process of oxidation with Shromic Acid of the Glucoside Coniferin, which occurs in the cambium of various coniferous woods" (37). Later, in 1891, the French chemist, De Taire, extracted vanillin from eugenol, which occurs in oil of cloves. This was first placed on the market at $12.00 an ounce. The latter is still the primary source of commercial "vanillin". Of late, however, vanillin has been produced in large quantities from wood pulp. This, the original Tiemann process, is that which is used in Germany today. Artificial vanillin has also been obtained by electrolysis from sugar, from asafoetida (*Ferula asa-foetida* L.), Siam benzoin (*Styrax tonkinensis* (Pierre) Craib) and from a coal tar product. "Other materials were used as a base to produce this important aromatic chemical, namely Guaiacel Orthe Anisidine" (37). Vanillin can also be produced from heliotropine which, in turn, is made from safrol. "The latter can be made from Oil of Sassafras, which is a distillate of Sassafras Bark" (37). Since sassafras (*Sassafras albidum* (Nutt.) Nees) grows rather extensively in the Carolinas, Kentucky and elsewhere in the eastern and central United States, this source of artificial vanillin should almost be sufficient if all other sources were made unavailable. Vanillin has been synthesized from waste paper pulp, and is found in asparagus, dahlia, lupine seeds and seeds of the common wild rose (54), as well as in the leaves of the vanilla plant itself. "Vanillin does not appear to have any physiological action on human beings when taken in small doses, as much as 10 or 15 grains having been administered without noxious results. On small animals, however, such as frogs, it appears to act as

a convulsive. It has been suggested as a stimulant of an excito-motor character in atonic dyspepsia " (32).

A number of imitation vanilla extracts, that may or may not contain a certain percentage of pure vanilla extract, have been placed on the market. A small amount of pure vanilla, as little as ten percent, usually greatly improves the flavor of these imitation extracts. Extract of tonka beans and coumarin are the primary sources of these extracts, although a number of synthetic chemicals are used, as ethyl vanillin, peperonal, various perfumes and cinnamic acid derivatives. Other materials which have been used are raisin and prune juices, maple sugar, St. John's bread (*Ceratonia siliqua* L.) and fenugreek (*Trigonella foenum-graecum* L.).

An unfortunate phase in the development of the vanilla industry is that relating to so-called " vanilla-poisoning " which gained prominence during the last century, especially in persons eating ice cream and vanilla ices. Foreign substances introduced through ignorance, accidentally or as adulterants in the vanilla beans and extract were found to be the source of most of the poisonings. Some instances of poisoning were thought to have been caused by the presence of tyrotoxicon, a poison found in milk which has undergone certain putrefactive changes, or perhaps by microscopic organisms in the vanilla, since the plantations are liable to the attack of *Bacterium putredinis* Weinberg et al. (32), etc. The presence of cardol, or the oil of the cashew nut, was also thought to cause some poisonings, since this was occasionally used to improve the appearance of the vanilla bean. " These cases are distinct from those in which the poisoning has been caused by the admixture of dangerous metallic substances " (32). In no instance was it found that vanilla, as such, caused poisoning.

Persons employed in handling vanilla occasionally suffer from an ailment know as " vanillism ". According to Ridley (54):

> " It takes the form of headache, gastric trouble, and urtication, or a kind of rash. The latter is perhaps caused by the crystals of oxalate of lime which are so abundant all through the plant. The juice of the leaves and stalks of some species at least is very irritating to the skin, and the leaf of the cultivated vanilla is used as a blistering agent in Réunion. That of the wild species of the Malay Peninsula, which produces a considerable amount of irritation on the softer part of the skin, is used by the Malays as a stimulant to the growth of the hair ".

Irritation of the skin is also thought to be caused by a mite (*Acarus*) which sometimes occupies the end of the bean (32).

Although science has devised substitutes for this popular flavoring material, vanilla, like so many other natural products which have been synthesized, should survive these encroachments. The delicate ephemeral essence of the natural product, which leaves no unpleasant after-taste, has not been completely captured by the test tube. There will doubtlessly always be a market for all first quality beans which may ever be grown.

Bibliography

LITERATURE CONSULTED [11]

1. Ames, O. Additions to the orchid flora of tropical America. Sched. Orch. No. 7. 36 pp.; illus. 1924.

[11] References mainly from Feldkamp, Cora L.—Vanilla: Culture, Processing, and Economics—A List of References, Library List No. 13 [Processed], U. S. Dept. Agr. Library. 1945. References marked with an asterisk (*) were not examined by Miss Feldkamp. Some of these latter references were added to Miss Feldkamp's list published in Childers, N. F. and Cibes, H. R. Vanilla Culture in Puerto Rico, Circular No. 28, Federal Experiment Station in Puerto Rico, U. S. Dept. of Agr. 1948. The author has added a few more items to this rather comprehensive list of references that is included here mainly for the convenience of research workers and others interested in closely studying the vanilla literature.

2. Andrews, H. C. The botanist's repository for new and rare plants. Vol. 8: pl. 538. 1808.
3. Anonymous. Cultivation of the vanilla bean in Mexico. Sci. Amer., Sup. **47**: 19580. 1889.
4. ———. Cultivo de la vainilla. Soc. Agr. Mexicana, Bol. **24**: 415–417. 1900.
5. ———. Curing of vanilla. Jamaica Agr. Soc., Jour. **36**: 333–335. 1932.
6. ———. Outlook for vanilla cultivation in Puerto Rico. Puerto Rico Bur. Agr. & Ind. Res. 62 pp. 1935.
7. ———. Supports for vanilla. Agr. News [Barbados] **4**: 297. 1905.
8.* ———. The cultivation of vanilla. Agr. News [Barbados] **13**: 402–403. 1914.
9. ———. The vanilla. Pharm. Jour. & Trans. III. **5**: 24–25. 1875.
10. ———. The wild vanilla plant. Pharm. Jour. & Trans. III. **5**: 489–490. 1875.
11. ———. Vanilla at Fiji. Kew Roy. Bot. Gard., Bull. Misc. Inf. **1894**: 208–211.
12. ———. Vanilla: bonanza or bubble? Government in Puerto Rico has spent hundreds of thousands on the development of vanilla in recent years. What can Puerto Rico expect of this new crop? Econ. Rev. Puerto Rico **2**(3): 6–17; illus. 1938.
13. ———. Vanilla cultivation at St. Vincent. Agr. News [Barbados] **12**: 116. 1913.
14. ———. Vanilla. Hawaii Agr. Exp. Sta., Rep. **1903**: 402–403. 1904; **1919**: 37. 1920.
15. ———. Vanilla. Mo. Bot. Gard., Bull. **3**: 109–112; illus. 1915.
16. ———. Vanilla. Queensland Agr. Jour. **4**: 477–483; illus. 1899.
17. Baer, S. H. Vanilla beans and vanilla extract: history of the product and its use in ice cream. Ice Cream Rev. **17**(8): 32–34. 1934.
18. Bouriquet, G. Les maladies du vanillier à Madagascar. Ann. Cryptogamie Exot. **6**: 59–78; illus. 1933.
19. Burnett, J., Company. About vanilla. 44 pp.; illus. 1900.
20. Chalot, C., and Bernard, U. Culture et préparation de la vanille. 215 pp.; illus. 1920.
21.* Childers, N. F., and Cibes, H. R. Vanilla culture in Puerto Rico. Puerto Rico [Mayaguez] Agr. Exp. Sta., Circ. **28**; 94 pp.; illus. 1948.
22. Collens, A. E., and Warneford, F. H. S. Vanille. Antiqua (Leeward Islands) Govt. Print. Off. 11 pp. 1925.
23. Conter, F. E. Vanilla cultivation in Hawaii. Hawaii Agr. Exp. Sta., Press Bull. **6**; 8 pp. 1903.
24. Correll, D. S. The American species of "leafless" vanillas. Am. Orch. Soc., Bull. **15**: 328–333; illus. 1946.
25. ———. Vanilla: its history, cultivation and importance. Lloydia **7**: 236–264. 1944.
26. Cunningham, C. H. Vanilla production in Mexico. U. S. Bur. Foreign & Dom. Com., Rep. **274**: 826–827. 1920.
27. Dillon, G. W. The story of vanilla. Am. Orch. Soc., Bull. **10**: 339–343; illus. 1942.
28. Dow, J. H. Vanilla beans and vanilla extracts. Am. Drug & Pharm. Rec. **43**: 130–131. 1903.
29. Etherlington, I. The leading spices of the world; vanilla: observations by an expert on cultivation and curing. Tea & Coffee Trade Jour. **12**: 864–866; illus. 1907.
30. Fauchere, A. Culture de la vanille à Madagascar. Jour. d'Agr. Trop. **14**: 105–109. 1914.
31. ———. Vanilla culture in Madagascar. Madagascar Buil. Econ. **14**(2): 122–126. 1914.
32. Ferguson, A. M., and Ferguson, J. All about spices. p. 149–184. [Reprint of various articles and items relating to vanilla]. Colombo, Ceylon, 1889 (?).
33. Galbraith, S. J. Vanilla culture as practiced in the Seychelles Islands. U. S. Dept. Agr., Bull. **21**; 24 pp. 1898.
34. Gnadinger, C. B. Vanilla. 60 pp. Minneapolis, McLaughlin Gormley King Co., 1929.
35. Hooker, J. D. Vanilla planifolia, native of Mexico. Curtis's Bot. Mag. 117. III. **47**: t. 7167. 1891.
36. Hoover, C. L. The vanilla industry of Netherlands India: elaborate report on source of vanilla not commonly considered of great importance. Spice Mill **49**: 922, 924–926. 1926.
37. Katz, A. E. Natural and synthetic flavoring materials, etc. Spice Mill **66**: 12, 34–35. 1943.
38. King, A. R. "The little pod" of Mexico; the story of the Mexican vanilla bean. 23 pp.; illus. New York, The Aromanilla Co., Inc., 1944.
39. Knudson, L. Germination of seeds of vanilla. Am. Jour. Bot. **37**: 241–247; illus. 1950.
40. ———. Orchids in industry—vanilla. Am. Orch. Soc., Bull. **10**: 131–132. 1941.
41. Lecomte, H., and Chalot, M. C. La vanillier: sa culture, préparation et commerce de la vanille. 228 pp.; illus. 1901.
42. Mallory, L. D., and Cochran, W. P. Mexican vanilla production and trade. For. Agr. **5**: 469–488; illus. [Processed]. 1941.

43. ———, Walter, D. F., and Walter, Karolyne. Mexico's vanilla production. For. Comm. Weekly **7**: 8–10, 23. 1942.
44. Marast, C. Vanilleries sous cocotiers dans le Bas-Sambirano. Agron. Colon [Italy] **6**: 71–72. 1920. [Eng. trans. in Agr. News [Barbados] **19**: 411. 1920].
45. Matschat, C. H. Vanilla—the orchid of commerce. Orch. Rev. **42**: 46–50. 1934.
46. McClelland, T. B. Vanilla: a promising new crop for Puerto Rico. Puerto Rico Agr. Exp. Sta., Bull. 26; 32 pp. 1919.
47. Morren, C. Sur la fructification de la vanille obtenue au moyen de la fécondation artificielle. Compt. Rend. Acad. Sci. [Paris] **6**: 489–492. 1838; Jour. d'Agr. Prat. **2**: 114–115. 1838–39.
48. ———. On the production of vanilla in Europe. Ann. & Mag. Nat. Hist. I. **3**: 1–9. 1839.
49. Narodny, Leo H. Vanilla-growing on Dominica. Jour. N. Y. Bot. Gard. **48**: 33–37; illus. 1947. Reprinted in Agr. Jour., Dept. Agr., Fiji **18**: 88–89. 1947.
50. Neumann, E. Growing and processing vanilla. Am. Perf. & Ess. Oil Rev. **46**(9): 57, 59. 1944.
51. O'Connor, C. A. Notes on vanilla cultivation. Mauritius Dept. Agr. Lft. **34**; 5 pp. 1933.
52. Plumier, P. C. Nova Plantarum Americanarum genera, p. 25. 1703.
53. Poore, C. Mexico's vanilla; pre-conquest heritage. Mex. Am. Rev. **12**(11): 8–10; illus. 1944.
54.* Ridley, H. N. Spices. pp. 23–93. 1912.
55. Rolfe, R. A. A revision of the genus *Vanilla*. Jour. Linn. Soc., Bot. **32**: 439–478. 1896.
56. ———. Vanillas of commerce. Kew Roy. Bot. Gard., Bull. Misc. Inf. **104**: 169–178. 1895.
57. Rowntree, S. W. Vanilla. Trinidad Roy. Bot. Gard., Bull. Misc. Inf. **3**(17): 133–147; illus. 1898. [Trans. from Sempler's Die tropische Agricultur].
58. Rusby, H. H. Distribution, habitat, cultivation and curing of vanilla. Merck's Rep. **7**: 74–75. 1898.
59. Salisbury, R. A. The Paradisus londinensis: containing plants cultivated in the vicinity of the metropolis, pl. 82. 1807.
60. Schlotterer, R. C. Vanilla in a changing world. Ice Cream Trade Jour. **36**(7): 10, 49. 1940.
61. Small, J. Vanilla: a pocket-lens study. Food-processing, Packeting, Marketing, pp. 137–141; illus. 1942.
62. Stanislaus, I. V. S. The vanilla pod. Tea & Coffee Trade Jour. **42**: 528, 530, 532, 674, 676, 678. 1922.
63. Tucker, C. M. Vanilla root rot. Jour. Agr. Res. **35**: 1121–1136; illus. 1927 (pub. Mar. 10, 1928).
64. Vicente, Gilda C., and Jones, M. A. Chemistry of vanilla processing. Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. **1946**: 38–43. 1947.
65. Weed, E. G. Vanilla, how to buy and use it. Canad. Dairy & Ice Cream Jour. **22**(9): 28–29, 44. 1943.
66. Whymper, R. Vanilla, an aromatic note. Mfg. Confectioner **24**(7): 16–18; illus. 1944.

Additional Literature

General

Allman, S. L. Control of Queensland fruit fly. Caged tree tests. Agr. Gaz. New So. Wales **52**(5): 281–282; illus. 1941.

Anonymous. La vainilla. Rev. de Agr. de Puerto Rico **28**: 328–342. 1936.

———. Sur la vanille. Paris Acad. Sci., Mém. 1722: 58–62. 1724.

———. Vanilla fragrans. Orch. Rev. **32**: 323–325; illus. 1924.

Bennett, C. W. Vanilla, and other cultures in Réunion; report for the years 1895–96 on the trade and agriculture of Réunion. Jamaica Bot. Dept., Bull. (n.s.) **7**(1): 8–14. 1900.

Bois, D. La vanille de Tahiti. Soc. Nat. d'Acclim. France, Bull. **63**: 174–176. 1916.

Busse, W. Ueber Gewürze. IV. Vanille. Arb. König. Gsndhtsamt. **15**: 1–113; illus. 1898–1899.

Castro Cancio, J. De. La industria vainillera; compilación de datos referentes a la vainilla, sobra historia, geografia, siembra, cultivo, beneficio, etc. . . . a peticion del disputado Manlio Fabio Altanicrano. 12 pp. Mexico, D.F. (Imprenta de la Secretaría Relaciones Exteriores). 1924.

Chalot, C. La vanille des colonies françaises et la vanilline chimique. Agr. Prat. Pays Chauds **9**: 271–281; illus. 1909.

Cornaillac, G. El cafe, la vanille, el cacao y el té: cultivo, preparación, exportación, classificación comercial; gastos, rendimiento. 480 pp.; illus. Barcelona, F. Sabater, 1903.

Desruisseaux, P. A. Contribution à l'étude de la vanille. Agr. Prat. Pays Chauds **13**: 265–276; illus. 1913.

Fernández R., E. La vainilla. Mex. Sec. Relac. Ext. Rev. del Com. Exterior **3**(1): 37–60. 1939.

Flückiger, F. A., and Hanbury, H. Pharmacographia; a history of the principal drugs of vegetable origin, met with in Great Britain and British India. Ed. 2, 803 pp. 1879.

Francois, E. Les produits malgaches: la va-

nille. Rev. de Madagascar No. 5: 39–56; illus. 1934.

Hart, J. H. Vanilla planifolia. Trinidad Roy. Bot. Gard., Bull. Misc. Inf. 21: 240; illus. 1894.

* Jackson, J. R. Vanilla. Pharm. Journ. III. 5: 885–886. 1875.

* Lewis, B. L. The story of pure vanilla with recipes. Vanilla Bean Assoc. Am., Inc., 1951.

* Livermore & Knight Co. The story of vanilla. 30 pp.; illus. 1926.

Lloyd, J. U. Vanilla planifolia; monographic description. West. Drug 19: 548–554; illus. 1897.

López Tuero, F. Vanilla. Rev. de Agr. [Santo Domingo] 3: 393–397. 1907.

López Y Parra, R., and Marín, L. Breves apuntes sobre el cultivo de la vainilla. Agr. y Ganad. 18(4): 19–21; (5): 15–21. 1943.

López Y Parra, R. La vainilla. Soc. Agr. Mexicana, Bol. 23: 767–772, 790–794, 809–816, 872–876. 1899.

* Maldonada, A. Vainilla de Moyobamba. Fac. de Med. Lab. de Farm., Lima, No. 2: 152–155; illus. 1921.

Meunier, P. La vanille. Parfums de France 9: 84–94; illus. 1931.

Parker, J. R., and Seamans, H. L. Experiments with grasshopper baits. Jour. Econ. Ent. 14: 138–141. 1921.

Puerto Rico [Mayaguez] Agr. Exp. Sta. Culture and processing of vanilla, insect pests and plant diseases. Puerto Rico [Mayaguez] Agr. Exp. Sta., Ann. Rep. 1909: 23; 1910: 39; 1911: 30; 1912: 29; 1913: 23–24; 1914: 25; 1915: 32–33; 1916: 23–24; 1917: 26–28, 29; 1918: 10–11; 1919: 9, 18–19; 1920: 17–18; 1921: 11–12; 1922: 8; 1923: 15; 1924: 28–29; 1925: 26–28; 1936: 11–12, 23–26; 1937: 16–26, 93; 1938: 18–25, 118–121, 125–127; 1939: 2–27, 117–119; 1940: 5–18; 1941: 3–7; 1942: 22–25; 1943: 32–35; 1944: 34–38; 1945: 44–53; 1946: 37–43. 1916–1947.

* Puerto Rico Emergency Relief Administration. Bur. Agr. & Ind. Res. Sobre la producción de la vainilla en la zona cafetera de Puerto Rico. Puerto Rico Emergency Relief Agency Bull. 1, 8 pp.; illus. 1935.

Sawer, J. C. Odorographia, a natural history of raw materials and drugs used in the perfume industry. Vol. 1; 383 pp. 1892.

Schaefer, C. The vanilla bean in Mexico. U. S. Cons. Rep. 46(170): 395–396. 1894.

Texas Agricultural Experiment Station. Vanillin as a poison bait. Tex. Agr. Exp. Sta., Ann. Rep. 1928: 48. 1929.

Utermark, W. L. Vanille, vanilline, vanille-extracten. Kolon. Inst. Amsterdam, Afd. Handelsmus, No. 3, Meded., No. 17, 116 pp.; illus. 1922.

Wildeman, E. de. Quelques notes sur les vanilliers africains. Rev. d'Hist. Nat. Appl. (Pt. I) 2: 144–147, 184–190, 222–224. 1921.

Wythers, G. Vanilla planifolia. Gard. Chron. III. 25: 213; illus. 1899.

Zeck, E. H. Vanilla. Austral. Nat. 7: 116–118. 1929.

Botany

* Ames, O., and Correll, D. S. Orchids of Guatemala, No. 1: 54–60; illus. 1952.

Beck, M. Von, and Lerchenau, G. Die Futterschuppen der Blüten von *Vanilla planifolia* Andr. Akad. Wiss. Wien, Math. Nat. Kl. Sitzber. Abt. 1, 121: 509–521; illus. 1912.

Constantin, J., and Bois, D. Sur trois types de vanilles commerciales de Tahiti. Compt. Rend. Acad. Sci. [Paris] 161: 196–202. 1915.

* Correll, D. S. Native orchids of North America north of Mexico. pp. 155–163. 1950.

Fischer, E. B., and others. Vanilla (change in definition). Am. Pharm. Assoc., Nat. Form. Com., Bull. 10: 20–22. 1942.

Gleason, H. A. *Vanilla planifolia*. Addisonia 14(4): 49–50; illus. 1929.

Guignard, L. Note sur une modification du tissu sécréteur du fruit de la vanilla. Soc. Bot. France, Bull. 33: 348–350. 1886.

———. Sur la pollinisation et ses effets chez les orchidées. Ann. Sci. Nat. VII. Bot. 4: 202–240. 1886.

Heckel, E. Sur la structure anatomique des vanilles aphylles. Compt. Rend. Acad. Sci. [Paris] 129: 347–349. 1899.

Hoffmann, K. Cytologische Studien bei den Orchidaceen. Ber. Deut. Bot. Ges. 47: 321–326. 1929.

Hurel-Py, G. Étude des noyaux végétatifs de *Vanilla planifolia*. Rev. de Cytol. et de Cytophys. Veg. 3(2/4): 129–133; illus. 1939.

Jacob de Cordemoy, H. Contribution à la biologie du vanillier. Jour. d'Agr. Trop. 4: 104–106. 1904.

———. Sur une anomalie de la vanille. Rev. Gén. Bot. 11: 258–267; illus. 1899.

McClelland, T. B. Influence of foreign pollen on the development of vanilla fruits. Jour. Agr. Res. 16: 245–252; illus. 1919.

Moore, J. W. New and critical plants from Raiatea. Bernice P. Bishop Mus. Bull. 102, pp. 3–53. 1933.

Rüdiger, W. Die Sprossvegetationspunkte einiger Monokotylen. Beitr. Biol. Pflanz. 26: 401–433; illus. 1939. "Vanilla planifolia", pp. 434–438; illus.

Culture

Anonymous. A method of pruning vanilla. Agr. News [Barbados] 10: 228–229. 1911.

———. Supports for vanilla. Agr. News [Barbados] 4: 297. 1905.

*———. Vanilla. Kew Roy. Bot. Gard., Bull. Misc. Inf. **1888**: 76–80; illus.

———. Vanilla in Seychelles. Kew Roy. Bot. Gard., Bull. Misc. Inf. 136/137: 93–95. 1898.

———. Informaçoes sobre a baunilha, sua cultura e preparação. São Paulo Bol. de Agr. **11**: 789–802; illus. 1910.

Blitzner, R. Erfahrungen über Kultur und Präparation der Vanille in Deutsch-Ostafrika. Tropenpflanzer **6**: 164–174. 1902.

Blokzeyl, K. R. F. El cultivo de la vainilla en la isla de Java. Hacienda **26**: 77; illus. 1931.

*Brander. Cultivation of vanilla in Tahiti. Kew Roy. Bot. Gard., Bull. Misc. Inf. **1894**: 206–208.

Brazil. Serviço de Informaçoes. Cultura da baunilha. Extracto revisto pelo Dr. Ribeiro de Castro. 12 pp.; illus. 1916.

Cairo, N. A baunilheira prospera admiravelmente no Brasil inteiro. Sitios e Fazendas **5**(3): 60. 1940.

Catoni, L. A. El cultivo de la vainilla en Puerto Rico. Rev. de Agr. de Puerto Rico **5**(6): 11–23. 1920.

Chalot, C. La vanille à Madagascar. Parfumerie Mod. **16**: 63–70, 83–89; illus. 1923.

*Constantin, J. N. Sur trois types de bailles commerciales de Tahiti. Compt. Rend. Acad. Sci. [Paris] **161**: 196–202. 1916.

Constantin, J. Remarques sur la végétation et la culture vanillier. Jour. d'Agr. Trop. **5**: 163–164. 1905.

*David, P. A. Vanilla culture in the College of Agriculture at Los Baños. Philippine Agr. **33**: 239–249. 1950.

De Faymoreau, A. Les grandes exploitations agricoles à Madagascar. Rev. Gén. Sci. Pures et Appl. **6**: 708–714; illus. 1895.

Delteil, A. La vanille, sa culture et sa préparation. Ed. **5**, 64 pp. 1902.

Desvaux. Quelques notions nouvelles sur les vanilles et la culture de l'espèce commerçable. Ann. Sci. Nat. III. Bot. **6**: 117–123. 1846.

Díaz Durán, E. La vanilla, su cultivo, el beneficio y algunos apuntes sobre apicultura como un agente auxiliar económico para la fecundación. 36 pp. Guatemala, Ministerio de Fomento. 1899.

Dupont, P. R. The vanilla industry: manuring experiments. Seychelles Agr. & Crown Lands, Ann. Rep. **1916**: 6, 9.

Fontecilla, A. Breve tratado sobre el cultivo y beneficio de la vainilla. 65 pp.; illus. Mexico, Biblioteca Agrícola de la Secretaria de Fomento, 1898.

Grandeau, L. Contribution à l'étude du vanillier. Ann. Sci. Agron. **2**: 295–305. 1897.

Hoffman, W. Die Kultur der Vanille. Varität: *Vanilla planifolia* u. *Vanilla pompona*. Neues Handb. Trop. Agr. **43**: 1–30; illus. 1931.

*Inkersley, A. Vanilla culture in the Hawaiian Islands. World To-day **9**: 1012, 1013. 1905.

Jones, A. B. Cultivation of the vanilla bean in Mexico. U. S. Cons. Rep. **60**(224): 151–155. 1899.

Jones, J. Vanilla cuttings. Agr. News [Barbados] **14**: 41. 1915.

*Knowlton, F. H. Vanilla and its cultivation. Pop. Sci. News **29**: 1–2; illus. 1895.

Lamsfus, E. Cultivo de la vainilla en Cuba. Cuban Est. Exp. Agron., Circ. **37**: 36–40; illus. 1909.

Lemcke, H. Die Kultur der Vanille in Mexiko. Tropenpflanzer **4**: 130–139. 1900.

Lopez Y Parra, R. La vainilla, su cultivo y beneficio en la República Mexicana y en el extranjero y algunas consideraciones sobre el perfeccionamiento de este rico producto agrícola. 78 pp. México, Impr. y Fototipia de la Secretaría de Fomento, 1911.

Medina, E. H. Studies of the shade requirements of vanilla. Univ. Puerto Rico, Jour. Agr. **27**: 27–37; illus. 1943.

———. The value of utilizing shade in the growing of vanilla. Univ. Puerto Rico, Jour. Agr. **27**: 117–124; illus. 1943.

Meinecke, E. P. Les vanillières de Tahiti et de Moorea. Rapport présenté à le gouverneur des établissements français de l'Oceanie et à M. M. les members de la Chambre d'Agriculture. 44 pp. Papeete, Impr. M. Barrier, 1916.

Newport, H. Vanilla culture for tropical Queensland. Queensland Agr. Jour. **24**: 184–189; illus. 1910.

O'Conor, J. E. Vanilla: its cultivation in India. Rev. ed., 25 pp.; illus. Calcutta, Off. Sup't. Gov't. Print., 1881.

Páez, C. J. Instrucciones para el cultivo de la vainilla. Rev. de Agr. y Com. [Panama] **3**(33): 44–56. 1944.

Pennington, C. F. Suggested types of vanilla culture for Puerto Rico. Rev. de Agr. de Puerto Rico **33**(4): 636–640. 1941.

*———. Vanilla pollination is no mystery. Rev. Agr., Ind. y Com., Puerto Rico **35**: 225–233; illus. 1944.

Percival, J. B. Cultivo de la vainilla. Hacienda **16**: 474–476; illus. 1921.

Perret, V. Cultures de la vanille, de la vigne, du cafeier et du murier combinées avec l'élévage du ver à soie en Nouvelle-Calédonia. Soc. Nat. d'Acclim. France, Bull. **45**: 180–182. 1898.

Perrier De La Bathie, H. Les vanilles de Madagascar. Mus. d'Hist. Nat. Bull. III. **6**: 193–197. 1934.

Pittier, H. Notas sobre el cultivo de la vainilla. Hacienda **22**: 268–270; illus. 1927.

Preuss, P. Expedition nach Central und Südamerida. 452 pp.; illus. Berlin, Verlag des Kolonial-Wirtschaftlichen Komitees, 1901.

———. Kultur und Aufbreitung der Vanille in Mexiko. Ber. Deut. Pharm. Ges. **11**: 24–40. 1901.

Pynaert, L. La culture de la vanille: la fructification du vanillon au Jardin Colonial de Laeken. Agr. et Élévage **11**: 33–36, 52–54. 1937.

Rodriguez Iñigo, D. El cultivo de la vainilla. Almanaque Agr. de. Puerto Rico **1942**: 127–135. 1942.

Rollot, C. Documentation sur la vanille. Madagascar Bull. Econ. **21**: 1–18; illus. 1924.

Semler, H. Die tropische Agrikultur, ein Handbuch für Pflanzer und Kaufleute. Ed. 2, v. 2, 858 pp.; illus. 1900.

Stühlmann, F. Notizen über die Landwirtschaft auf "La Reunion". Tropenpflanzer Beihefte **2**: 1–29; illus. 1901.

Suckling, J. J. C. The cultivation and hand pollination of vanilla. Fiji. Dept. Agr., Agr. Jour. **11**: 22–23. 1940.

* Urpia, A. Culture of vanilla (*Vanilla planifolia*). [In Portuguese]. Bahia. Sec. da Agr., Ind. e Com. Serv. Divulg. B. II. **45**(3): 163–177. 1949.

Valdivia, M. A. El cultivo de la vainilla. Hacienda **18**: 374–376; illus. 1923.

Van Essen, G. La vainilla. Suelo Argentino **2**: 606–607; illus. 1943.

Varigny, C. De. Fertilization of the vanilla flowers by bees. Bombay Nat. Hist. Soc., Jour. **8**: 555–556. 1894.

Vizcarrondo, R. El cultivo de la vainilla en Puerto Rico. Rev. de Agr. de Puerto Rico **30**: 413–421; illus. 1938.

Wigman, H. J. Vanilla Sw. Indische Cult. [Teysmannia] **16**: 127–132; illus. 1931.

Wildeman, E. De. Les plantes tropicales de grande culture. 301 pp.; illus. 1902.

Diseases

Ciferri, R. Notae mycologicae et phytopathologicae. Riv. di Patol. Veg. (n.s.) **17**: 209–316; illus. 1927.

* Dale, W. T. Report on a visit to Dominica, B. W. I. 11 pp. [Processed]. Trinidad, 1945.

Delacroix, G. Sur deux maladies du vanillier. Soc. Mycol. France, Bull. **18**: 274–284; illus. 1902. Also in Agr. Prat. Pays Chauds **1**: 680–688; **2**: 78–79. 1902.

Kevorkian, A. G. A disease new to Puerto Rico was discovered causing losses in vanilla. Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. **1939**: 117–119. 1940.

Massee, G. Vanilla disease. Kew Roy. Bot. Gard., Bull. Misc. Inf. **65/66**: 111–120; illus. 1892.

Maublanc, C. Maladies du vanillier. Agr. Prat. Pays Chauds. **12**: 177–188, 277–287; illus. 1912.

Pavarino, G. L. Batteriosi della "*Vanilla planifolia*" Andr. (*Bacterium Briosianum*, n. sp.). R. Accad. Naz. Lincei, Cl. Sci. Fis., Mat. e Nat. V. **20**(2): 161–162. 1911.

* Pennington, C. F. What can we do about vanilla root rot. Rev. Agr., Ind. y Com., Puerto Rico **36**: 25–31; illus. 1945.

———. Vanilla diseases. Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. **1938**: 125–127. 1939.

Petch, T., and Ragunathan, C. The fungi associated with disease in vanilla. Ceylon Jour. Sci. Bot. **10**: 181–196; illus. 1927.

Ragunathan, C. Soft rot of *Vanilla planifolia* Andrews. Ceylon Dept. Agr., Yearbook **1924**: 52–55.

Roque, A. Root disease of vanilla. Puerto Rico [Rio Piedras] Agr. Exp. Sta., Rep. **1936**: 51. 1937.

Shear, C. L., and Wood, A. K. Studies of fungus parasites belonging to the genus *Glomerella*. U. S. Dept. Agr., Bur. Plant Ind., Bull. 252. 110 pp.; illus. 1913.

Staner, P. Les maladies du vanillier à Eala. Bull. Agr. Congo Belge **19**: 85–90; illus. 1928.

Tucker, C. M. A root disease of vanilla. Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. **1923**: 15. 1924.

Turconi, M. Note di patologia vegetale. 1. Un'infezione di *Botrytis cinerea* Pers. in giovani frutti di vainiglia (*Vanilla planifolia* Andr.). Riv. di Patol. Veg. (n.s.) **13**: 157–161. 1923.

* Verplancke, G., and Claessens, B. Bijdrage tot de flora der woekerzwammen van België. 3. Nieuwe zwammen gevonden van Januari tot April 1934. Naturwet. Tijdschr. **16**: 182–192; illus. 1934. "Vanilla: a tabulation of the *Gloeosporium* and *Colletotrichum* spp. on Orchidaceae, with hosts, spore measurements, and citations", p. 189. Abs. in Biol. Abs. **10**: 9200. 1936.

Zimmermann, A. Ueber einige Krankheiten und Parasiten der Vanille. Centbl. Bakt. Parasitenk. 2 Abt. **8**: 469–481; illus. 1902.

Insects

Bordage, E. Notes biologiques recueillies à l'Ile de la Réunion. Bul. Sci. France et Belg. **47**: 377–412; illus. 1914.

———. Sur les parasites animaux et végétaux du vanillier. Cong. Int. d'Agr., 6th, Paris, 1900, II: 315–320. Also in Rev. Agr. de l'Ile Réunion **7**: 70–74, 142–149. 1901.

François, E. Note complémentaire sur un nouvel ennemi de la vanille. Rev. Bot. Appl. et d'Agr. Colon. **8**: 859–860. 1928.

———. Sur un nouvel ennemi de la vanille (*Perrissodores oblongus* Hust.). Rev. Bot. Appl. et d'Agr. Colon. **8**: 617–620. 1928.

Frappa, C. Contribution à l'étude des Curculionides nuisibles aux plantes cultivées à Madagascar. Madagascar Bull. Econ. Doc.-Études **27**(1): 241–259. 1930.

———. Les principaux insectes nuisibles aux cultures de Madagascar. Rev. Bot. Appl. et d'Agr. Colon. **17**: 513–516. 1937.

Gater, B. A. R. Annual report of the Entomological Division for 1924. Malayan Agr. Jour. **13**: 220–226. 1925.

Pham-Tu-Thien. Un insecte nuisible aux feuilles de vanilliers en Cochinchine (*Spilarctia multiguttata* Wlkr.). Bull. Econ. de l'Indochine **25**: 438–441; illus. 1922.

Plank, H. K., Pennington, C. F., and Kevorkian, A. G. Insects attacking vanilla; survey of vanilla pests revealed four insects causing limited damage. Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. **1938**: 118–121; illus. 1939.

* Raynaud, B. Notice sur deux insectes ennemis de la vanille. Soc. d'Études Océan, Bull. **10**: 39–42. 1927.

Sawyer, H. H. Parasites infecting vanilla beans. Am. Drug. & Pharm. Rec. **27**: 109; illus. 1895.

Economics

Anonymous. Army using vanilla tablets. New York Times, Nov. 30, 1942; **16**: 7.

———. Exports of vanilla beans, Society Islands, French Oceania, 1943–44. Foreign Com. Weekly **16**(4): 25. 1944.

———. La decadencia de nuestra industria vainillera. Mex. Sec. Relac. Ext., Rev. Com. Ext., pp. 9–15; August, 1934.

———. La production de la vanille dans les colonies françaises. Franc. Min. Colon., Bull. de l'Off. Colon. **7**: 209–249. 1914.

———. Mexican vanilla crop, 1940–1943. Foreign Com. Weekly **15**(11): 24. 1944.

———. Monografías commerciales: vainilla. Mex. Dir. Econ. Rural, Bol. Mens. 204: 372–390. 1943.

———. O.P.A. places price ceiling on vanilla beans Sept. 30. Ice Cream Rev. **26**(3): 104. 1942.

———. The prospect of vanilla growing in the West Indies. Agr. News [Barbados] **9**: 52–53. 1910.

———. Vainilla. Rev. Econ. [Mexico] **5**(5): 7–8. 1942.

———. Vanilla-bean crop in Society Islands. Foreign Com. Weekly **9**(2): 20–21. 1942.

———. Vanilla bean prices set by OPA. Oil, Paint & Drug Rep. **142**(14): 5, 83. 1942.

———. Vanilla tablet. New York Times, March 21, IV; **11**: 7. 1943.

Bague, J. Puerto Rico contemple el surgir de una nueva industria. La vainille se arraiga en sus montañas. Rev. de Agr. de Puerto Rico **33**(2): 206–220. 1941. English trans. in Rev. de Agr. de Puerto Rico **33**(3): 459–475. 1941.

* Banda, F. C. La vainilla y sus variados usos industriales. Agr. Venezol. **2**(22): 4–7; illus. 1938.

Beringer, G. M. Some commercial vanillas. Am. Jour. Pharm. **64**: 289–294. 1892; also in Pharm. Jour. III. **23**: 9–11. 1892, and Kew Roy. Bot. Gard., Bull. Misc. Inf. **69**: 212–215. 1892.

Coffin, P. L., Jr. Will vanilla force coffee into a supplementary position? Rev. de Agr. de Puerto Rico **32**(3): 444–446. 1940.

Diaz Lombardo, M. Vainilla: su mercado en los Estados Unidos. Mex. Sec. Relac. Ext., Rev. Com. Ext. **8**(9): 8. 1943.

Drake-Law, H. Vanilla. I. Cultivation, grading and marketing. II. Classification and grading. Food Manufacture **4**: 293–294. 1929; **5**: 101–103, 350–353; illus. 1930.

Faria Silveira, E. De. Possibilidades do cultivo da baunilha no Brasil. Rev. Rural Bras. **22**(261): 40–42. 1942.

Farley, G. H. The use of pure vanillin extract from an esthetic, commercial, and pure food standpoint, with brief history of its source. Wash. State Col., Inst. Dairying, Proc. (1932) **5**: 15–20.

García Cruz, M. Breve estudio monográfico del comercio de la vainilla en México. Mex. Dept. Antónomo de Prensa y Publicidad. Agricultura **2**(14): 59–67; (15): 69–78. 1939. [Vanilla trade of Mexico; tables show quantity and value of vanillin imports, 1930–1936; exports of vanilla, 1877–1898; exports, 1905–1937; and graphs show imports of vanilla and vanillin, 1930–1936; and exports of Mexican vanilla, 1925–37].

Glassford, J. Definitions and standards for flavoring extracts. Canning Age **15**: 334–336, 341–342. 1934.

Henning, A. Commerce of vanilla and vanillin. Merck's Rep. **7**: 104–105. 1898.

Lucas, P. S. Ice cream flavors have been affected by the war. Ice cream manufacturers encounter shortages of vanilla and vanilla substitutes, resulting in difference in quality of mix. Drastic scarcity of most fruit flavors. Am. Perf. & Ess. Oil Rev. **46**(5): 57, 61, 63. 1944.

McClelland, T. B. Present status of Porto Rican vanilla. Trop. Agr. [Ceylon] **63**: 376–378. 1924.

Mexico, Secretaria de Agricultura Y Fomento. Decreto que reglamenta la exploitación y comercio de la vainilla. Mex. Diario Oficial 127(39): 3–4. 1941.

*———. Vanilla: monografias comerciales. Mex. Dir. Econ. Rural. 20 pp.; illus. 1943.

Nolan, L. C. The story of vanilla. Agr. in the Americas 2: 32–34; illus. 1942.

Novoa, G. Vainilla—su mercado en Nueva York. Mex. Sec. Relac. Ext., Rev. Com. Ext. 8(5): 12. 1943.

Ortiz, H. G., and Noguera, V. E. Vainilla—su mercado en Estados Unidos. Mex. Sec. Relac. Ext., Rev. Com. Ext. 8(7): 10–14. 1943.

Pennington, C. F. Vanilla and the coffee regions of western Puerto Rico. Rev. Agr. de Puerto Rico 33(1): 184–186. 1941.

Rosenbaum, R. Vanilla: how are the world sources fairing as war drums beat? What is the outlook? Ice Cream Trade Jour. 37(1): 18–19, 64–65. 1941.

Schlotterer, R. C. Vanilla outlook. Oil, Paint & Drug Rep. 145(22): 48–49. 1944.

Series estadisticas-introducción a las series estadisticas de vainilla. Mex. Dir. Econ., Rural Bol. Mens. 201: 10–15. 1943.

Sommariva, C. La "Vanilla planifolia" e le sue possibilita di coltura in Riviera. Costa Azzurra Agr. e Floreale 18(3/4): 60–62; illus. 1938.

U. S. Dept. of Commerce. Mexican vanilla production and trade. U. S. Dept. Com., Ind. Ref. Serv., Pt. 3, Foodstuffs, No. 76, 7 pp. 1941. Culture and marketing, statistics of yield and production by states, 1935–1940, and exports 1937–1940.

*U. S. Tariff Commission. Summary of the tariff information, 1929 on Tariff Act of 1922. Schedule 1, Chemicals, oils, and paints. 419 pp. Washington, 1929. Vanilla beans: import statistics, 1919–1928; prices 1923–1928, p. 415.

*Waddel, A. F., and Schwarstrauber, E. M. Madagascar—island long famous for vanilla. U. S. Dept. Com., Foreign Com. Weekly 7(9): 6–9, 36–38; illus. 1942.

*Whitmore, H. B. Vanilla-bean production and trade. U. S. Dept. Agr., Foreign Agr. 10(1): 11–16; illus. 1946.

Patents

Balls, A. K., Kevorkian, A. G., and Arana, F. E. Process for curing vanilla beans. U. S. Patent No. 2,274,120. U. S. Patent Off., Off. Gaz. 535: 802. 1942.

Buel, H. Extraction method and apparatus. U. S. Patent No. 1,636,550. U. S. Patent Off., Off. Gaz. 360: 716; illus. 1927.

Gowen, J. K. Process of making vanilla extract. U. S. Patent No. 1,010,043. U. S. Patent Off., Off. Gaz. 172: 950–951. 1911.

Howell, E. M. Process of extracting essences and tinctures from vanilla-beans. U. S. Patent No. 921,251. U. S. Patent Off., Off. Gaz. 142: 414; illus. 1909.

*Montesquiou. Process and apparatus preparing vanilla. French patent No. 367,287. June 9, 1906. Chem. Abs. 1: 2434. 1907.

Sheehan, E. J. Oleoresin of vanilla. U. S. Patent No. 931,805. U. S. Patent Off., Off. Gaz. 145: 801. 1909.

Todd, U. G. Liquid-extracting means. U. S. Patent No. 1,787,625. U. S. Patent Off., Off. Gaz. 395: 1664; illus. 1930.

Wussow, A. F. Process for making vanilla and other flavoring extracts. U. S. Patent No. 1,515,714. U. S. Patent Off., Off. Gaz. 328: 617. 1925.

Processing and Chemistry

Anonymous. Baunilha e medicina. Chacaras Quintais 67(3): 341–342. 1943.

———. Monographs on floral odours, with notes on practical use. VIII. The scent of the hayfields, vanilla, lilac, elder flower. Perf. & Ess. Oil Rec. 13: 70–73. 1922.

———. Presto! New vanilla tablet to serve all flavoring needs of overseas forces. Spice Mill 66(1): 33–34. 1943.

———. Über die Vanille und das Vanillin. Chem. Zeit. 45: 696–698. 1921.

Arana, F. E. Action of a β-glucosidase in the curing of vanilla. Food Res. 8: 343–351; illus. 1943.

———. Chemistry of vanilla. Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. 1939: 2–14; illus. 1940.

——— and Kevorkian, A. G. Investigations of vanilla production and processing. Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. 1940: 5–18; illus. 1941.

——— and ———. Relation of moisture content to quality of vanilla beans. Puerto Rico Univ., Jour. Agr. 27(3): 107–116; illus. 1943.

*———. Vanilla curing and its chemistry. Puerto Rico [Mayaguez] Agr. Exp. Sta., Bull. 42, 17 pp.; illus. 1944.

*———. Vanilla investigations. Rev. de Agr. de Puerto Rico 34: 73–78. 1942.

*———. Vanilla curing. Puerto Rico [Mayaguez] Agr. Exp. Sta., Cir. 25, 21 pp.; illus. 1945.

——— and Kevorkian, A. G. Vanilla investigations (chemistry and processing). Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. 1939: 2–11, 14–22. 1940.

——— and Nelson, E. K. Vanilla processing and chemistry. Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. 1938: 18–25. 1939.

Arroyo, R. The fermentation of the vanilla bean. Puerto Rico [Rio Piedras] Agr. Exp. Sta., Rep. 1934: 47, 156. 1935.

Balls, A. K., and Arana, F. E. The curing of vanilla. Ind. & Eng. Chem., Ind. Ed. **33**: 1073–1075; illus. 1941. Spanish trans. in Rev. de Agr. de Puerto Rico **34**: 167–172. 1942.

——— and ———. Determination and significance of phenols in vanilla extract. Assoc. Off. Agr. Chem., Jour. **24**: 507–512. 1941.

——— and ———. Recent observations on the curing of vanilla beans in Puerto Rico. Proc. VIII Am. Sci. Cong., 1940, Phys. & Chem. Sci. Vol. **7**: 187–191. 1942.

Bartlett, K. A. Tincture of vanilla. Jour. Am. Pharm. Assoc. **9**: 706–708. 1920.

Behrens, J. Ueber das Vorkommen der Vanillins in der Vanille. Tropenpflanzer **3**: 299–303. 1899.

Bloom, A., and Tubis, M. Determination of vanillin in vanilla flavor. Jour. Assoc. Off. Agr. Chem. **25**: 783–784. 1942.

Bowers, W. G., and Moyer, J. Some vanillin oxidation products: methods of analysis which exclude them. No. Dak. Agr. Exp. Sta., Spec. Bull. **5**(16): 518–520. 1920.

Boyles, F. M., and Shanley, E. J. Alcohol in vanilla extract. Tea & Coffee Trade Jour. **47**: 121–122. 1924.

———. The relative flavoring value of true vanilla extract and vanillin solution. Spice Mill **45**: 1438–1440. 1922.

———. Vanilla extract; an analysis of methods of extraction and comparison of the best varieties, chemical composition of the beans. Tea & Coffee Trade Jour. **46**: 136–138, 140. 1924.

——— and Shanley, E. J. Vanilla extract in ice cream. Experiments of chemists show that there is no freezing out during storage of reasonable length. Tea & Coffee Trade Jour. **47**: 125–126. 1924.

Busse, W. Ueber die Bildung des Vanillins und der Vanillefrucht. Zeits. Untersuch. Nahr. Genüssmtl. **3**: 21–25. 1900.

Campbell, C. P. The manufacture of flavoring extracts. Spice Mill **47**: 794–800. 1924.

* Cernuda, C. F. A simple mathematical procedure for use in curing Vanilla to a desired moisture content. Trop. Agr. [Trinidad] **26**: 124–125. 1949.

Chace, E. M. The manufacture of flavoring extract. U. S. Dept. Agr., Yearbook **1908**: 333–342; illus. 1909; also in Spice Mill **33**: 124–126, 194–196. 1910.

Clemens, C. A. The lead number of vanilla extracts. Assoc. Off. Agr. Chem., Jour. **8**: 79–82. 1924.

Coblentz, V. The chemistry of vanillin. Merck's Rep. **7**: 75, 104. 1898.

Courtet, H. La vanille et la vanilline artificielle. Soc. Nat. d'Acclim. France, Bull. **58**: 19–24, 59–64, 73–77. 1911.

Dahlberg, A. C. Vanilla flavor for ice cream. Ice Cream Trade Jour. **28**(11): 33–34. 1932.

Dean, J. R., and Schlotterbeck, J. O. Vanilla extract. Jour. Ind. & Eng. Chem. **8**: 607–614, 703–709; illus. 1916.

Degroote, M. Concentrated vanilla compounds. Spice Mill **45**: 1042, 1044, 1046. 1922.

———. Designation of vanilla products. Tea & Coffee Trade Jour. **39**: 358, 360, 362. 1920.

———. Problems in vanilla percolation. Spice Mill **43**: 1470, 1472, 1474. 1920.

———. Vanilla powders. Spice Mill **44**: 312, 314. 1921.

Deloye, M. Le préparation et le commerce de la vanille aux Îles Comores. Agr. Prat. Pays Chauds (n.s.) **3**: 43–54, 115–125; illus. 1932.

Doherty, W. M. Vanilla: and a short and simple method for the determination of vanillin. Roy. Soc. New So. Wales., Jour. & Proc. **47**: 157–162; illus. 1914.

Dox, A. W., and Plaisance, G. P. A new method for the determination of vanillin in vanilla extract. Spice Mill **41**: 1424, 1426. 1908; also in Jour. Pharm. **88**: 481–484. 1916; **91**: 167–170. 1919.

Eder, R., and Schlumpf, E. Die Vanillinbestimmung in Vanilleschoten und in Vanillinzucker. Pharm. Acta Helvetiae **3**: 65–78. 1928.

Estes, C. A new qualitative test and colorimetric method for the estimation of vanillin. Jour. Ind. & Eng. Chem. **9**: 142–144. 1917.

Fellenberg, T. Von. Eine kolorimetrische Bestimmungsmethode von Vanillin in Vanille. Mitt. Geb. Lebensmtl. Untersuch. Hyg. **6**: 267–274. 1915.

Folin, O., and Denis, W. A new colorimetric method for the determination of vanillin in vanilla extracts. Jour. Ind. & Eng. Chem. **4**: 670–672. 1912.

Foot, F. N. The making of vanilla extract. Spice Mill **46**: 158–160. 1923.

Fryer, V. A. Vanilla extracts. Tea & Coffee Trade Jour. **18**: 21–26; illus. 1910.

Geret, L. Cumarin-Nachweis in Vanillin. Mitt. Geb. Lebensmtl. Untersuch. Hyg. **11**: 69–71. 1920.

Glendenning, T. Flavor in confections. V. Vanilla flavor. Mfg. Confec. **20**(5): 30–31. 1940.

Gnadinger, C. B. Effect of vacuum distillation on vanilla extract. Ind. & Eng. Chem. **19**: 342–344. 1927.

———. Identification of sources of vanilla extracts. Ind. & Eng. Chem. **17**: 303–304. 1925.

Gobley, T. W. Recherches sur le principe odorant de la vanille. Jour. Pharm. Chim. III. **34**: 401–405. 1858.

Goris, A. Sur la composition chimique des fruits verts de vanille et la mode de formation du parfum de la vanille. Compt. Rend. Acad. Sci. [Paris] **179**: 70–72. 1924.

Heckel, E. De l'action du froid et des anesthésiques sur les feuilles de l'*Angraecum fragrans* Thou. (Faham) et sur les gousses vertes de vanille. Compt. Rend. Acad. Sci. [Paris] **151**: 128–131. 1910.

Hess, W. H., and Prescott, A. B. Coumarin and vanillin: their separation, estimation, and identification in commercial extracts. Mich. State Dairy & Food Com., Rep. **1900**: 197–199.

Hubbard, W. S. Difficulties in the colorimetric estimation of vanillin. Jour. Ind. & Eng. Chem. **4**: 669–670. 1912.

Iserman, S. The chemistry of vanilla beans. Tea & Coffee Trade Jour. **19**: 21–26; illus. 1910.

J(ack), H. W. Vanilla: notes on curing Tahiti vanilla beans. Fiji. Dept. Agr., Agr. Jour. **11**: 22–23. 1940.

Jackson, H. L., and McGeorge, W. T., Jr. Lead number of vanilla extracts. Jour. Ind. & Eng. Chem. **1**: 478, 479. 1909.

Jaubert, G. F. La vanilline et la vanille au point de vue fiscal. Rev. Gén. Chim. Pure et Appl. **12**: 306–308. 1909.

Jeliff, S. E. Microscopical characteristics of vanilla. Merck's Rep. **7**: 75. 1898.

Kalish, O. Vanilla extract. Merck's Rep. **7**: 105–106. 1898.

Kessler, E. J. Vanilla flavoring extract and practical methods of its manufacture. I. Growth and selection of the beans. II. The selection of a solvent and including a discussion of alcohol and water. III. Methods of extraction employed in the manufacture of vanilla extract, discussing the processes and apparatus commonly used and offering suggestions of practical value to the manufacturer. IV. Recovering extractives from the exhausted beans, dilution, and storage. Glass Packer **2**: 325–327, 459–461. 1929; **3**: 24, 27, 140–141. 1930.

Kevorkian, A. G. Vanilla-processing studies. Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. **1939**: 14–18. 1940.

Kotake, Y. Über das Schicksal des Vanillins im Tierkörper. Zeits. Physiol. Chem. **45**: 320–325. 1905.

Krebs, W. Vanille. Pharm. Centralhalle Deut. (n.s.) **16**: 487–490, 503–507, 517–521. 1895.

Lecomte, H. Formation de la vanilline dans la vanille. Agr. Prat. Pays Chauds **13**(2): 3–14, 75–83. 1913.

———. Sur la formation du parfum de la vanille. Compt. Rend. Acad. Sci. [Paris] **133**: 745–748. 1901.

Lucas, P. S., and Merrill, A. C. Vanilla flavors do not freeze out of ice cream. Mich. Agr. Exp. Sta., Quart. Bull. **11**(3): 118–120. 1929.

Mange, C. E., and Ehler, O. Solubilities of vanillin. Ind. & Eng. Chem. **16**: 1258–1260; illus. 1924.

Martell, P. Vanille und Vanillin. Zeits. Untersuch. Nahr. Genüssmtl. **50**: 415–420. 1925.

Moroy, J. Les poudres de vanille. Ann. Falsif. **20**: 21–25. 1927.

Moulin, A. Dosage de la vanilline dans les vanilles. Soc. Chim. Paris, Bull. III. **29**: 278–280. 1903.

Parry, E. J. Parry's cyclopaedia of perfumery: a handbook on the raw materials used by the perfumer. Vol. 2: 433–840. [Vanilla, pp. 783–803; Vanillin, pp. 803–810]. 1925.

Pennington, C. F. Vanilla bean processing studies. Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. **1937**: 24–26. 1938.

———. Vanilla production and processing studies. Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. **1936**: 23–26; **1937**: 16–26. 1937–1938.

Pheteplace, W. D., Jr. La elaboración de extracto de vainilla segun los últimos dictados de la técnica. Hacienda **32**: 140–141; illus. 1937.

Phillips, S. B. Determination of the purity of vanillin. Analyst **48**: 367–373. 1923.

Pierce, H. B., Combs, W. B., and Borst, W. F. The use of true and imitation vanilla extracts in ice cream. Jour. Dairy Sci. **7**: 585–590. 1924.

Pontillon, C. Fermentation de la vanille: la vanilline. Rev. Bot. Appl. et d'Agr. Trop. **10**: 218–224. 1930.

Pougnet, J. Action des rayons ultraviolets sur gousses vertes de vanille. Compt. Rend. Acad. Sci. [Paris] **152**: 1184–1186. 1911.

Pritzker, J., and Jungkunz, R. Analytisches über Vanillin und Vanillinzucker. Chem. Zeitg. **52**: 537. 1928.

——— and ———. Über Vanille, Vanillin und ihre Mischungen mit Zucker. Zeits. Untersuch. Lebensmtl. **55**: 424–446. 1928. Trans. in Spice Mill **52**: 1496, 1498, 1672, 1674, 1676, 1862, 1864, 1866–1869, 2094, 2096, 2098–2101. 1929.

——— and ———. Ueber Vanillinzucker. Mitt. Geb. Lebensmtl. Untersuch. Hyg. **15**: 54–62. 1924.

Rabak, F. The effect of curing on the aromatic constituents of vanilla beans. Jour. Ind. & Eng. Chem. **8**: 815–821; illus. 1916.

Radcliffe, L. G., and Sharples, E. H. Vanillin, piperonal and coumarin. Perf. & Ess. Oil Rec. **15**: 396–402, 437–439; **16**: 20–23, 51–54, 87–92, 156–162, 197–199, 271, 353–355, 387–390. 1924–1925.

Riviere. Sur la composition chimique de la vanille de Tahiti. Ann. d'Hyg. et de Méd. Colon. **15**: 839–842. 1912.

Schellbach, H., and Bodinus, F. Ueber Vanillinzucker. Zeits. Untersuch. Nahr. Genüssmtl. **36**: 187–189; **38**: 292–293. 1918–1919.

Smith, B. H. The tincture of vanilla of the National Formulary. Jour. Ind. & Eng. Chem. **11**: 953, 954. 1919.

Stokkeby. Sur la vanille. Jour. Pharm. et Chim. IV. **3**: 76–77. 1886. [Confirms the work of Gobley reported in Jour. Pharm. et Chim. III. **34**: 401–405. 1858].

Taylor, H. M., and Konnerth, R. A. Flavoring qualities of vanilla tinctures. Am. Pharm. Assoc., Jour. **16**: 556–561. 1927.

Tiemann, F., and Haarmann, W. Ueber das Coniferin und seine Umwandlung in das aromatische Princip der Vanille. Ber. Deut. Chem. Ges. **7**: 608–623. 1874.

——— and ———. Ueber die Bestandtheile der naturlichen Vanille. Ber. Deut. Chem. Ges. **9**: 1287–1292. 1876.

Tiffeneau, M. Vanille et vanilline. Rev. Sci., No. 20: 622–626. 1909.

Totman, C. C. Vanilla and vanilla compounds. Ice Cream Rev. **14**(11): 49–50. 1931.

Towt, L. V. The use of the Mojonnier milk tester for the routine determination of vanillin with preliminary discussion of the Towt lead number. Jour. Dairy Sci. **12**: 469–472. 1929.

U. S. Food and Drug Administration. Definitions and standards for food products for use in enforcing the Food and Drugs Act. U. S. Food & Drug Admin., Serv. & Reg. Announc. Food and Drug, No. 2, 5th rev., 20 p. 1936. Vanilla extract, p. 16.

Vée, A. Note sur le givre de vanille. Jour. Pharm. et Chim. III. **34**: 412–413. 1858.

* Vicente, Gilda C., and Jones, M. A. Chemistry of vanilla processing. Spice Mill **68**(11): 65–66. 1945; **68**(12): 62. 1945.

* Walbaum, H. Das Vorkommen von Anisalkohol und Anisaldehyd in den Früchten der Tahitivanille. Wallachs Festschrift, **1909**: 649–653. Bericht von Schimmel & Co., **1909**: 140–141, Oktober. Miltitz b. Leipzig. Lab. von Schimmel & Co.

Warneford, F. H. S. Curing of vanilla. Trop. Agr. [Trinidad] **5**: 27–28. 1928; also in Trop. Agr. [Ceylon] **71**: 381–383. 1928.

Weed, E. G. Vanilla, preparation and types. Ice Cream Rev. **25**(7): 26–28, 42–44; illus. 1942.

West Indies Imperial Dept. of Agriculture. Curing of vanilla beans (*Vanilla planifolia*). West Indies Imp. Dept. Agr., St. Kitts-Nevis. Agr. Dept., Rep. **1917–1918**: 28–31; also in Trop. Agr. [Ceylon] **53**: 312–314. 1919.

Wichmann, H. J. Errors in gravimetric vanillin determinations in vanilla extract. Assoc. Off. Agr. Chem., Jour. **4**: 479–482. 1921.

———. A new lead number determination in vanilla extracts. Jour. Ind. & Eng. Chem. **13**: 414–418. 1921.

——— and Dean, J. R. Qualitative method for coumarin in vanilla extract. Assoc. Off. Agr. Chem., Jour. **4**: 254–255. 1920.

Wilson, J. B., and Sale, J. W. Evaluation of commercial vanilla oleoresins. Jour. Ind. & Eng. Chem. **18**: 283–285. 1926.

Wilson, J. B. Identification of flavoring constituents of commercial flavors. XI. Vanillin by means of the neutral wedge photometer. Assoc. Off. Agr. Chem., Jour. **25**: 155–159. 1942.

——— and Sale, J. W. Suitability of various solvents for extracting vanilla beans. Jour. Ind. & Eng. Chem. **15**: 782–784. 1923; **16**: 301–303. 1924.

Winton, A. L., and Silverman, M. The analysis of vanilla extract. Am. Chem. Soc., Jour. **24**: 1128–1135. 1902.

——— and Berry, E. H. The chemical composition of authentic vanilla extracts, together with analytical methods and limits of constants. Assoc. Off. Agr. Chem., Proc. **28**(1911): 146–158. 1912. [U. S. Bur. Chem., Bull. 152].

——— and ———. The composition of vanilla extract from Tahiti and Fiji beans. Assoc. Off. Agr. Chem., Proc. **29**(1912): 90–91. 1913.

——— and Bailey, E. M. La détermination de la vanilline, de la coumarine et le l'acétanilide dans les extracts de vanille. Rev. Int. Falsific. **18**: 79–80. 1905.

Toxic Effects

Arana, F. E. (Vanillism). Puerto Rico [Mayaguez] Agr. Exp. Sta., Rep. **1939**: 11–14; illus. 1940.

Arning, E. Vanilleauschlag. Deut. Med. Wochens. **23**: 435–436. 1897.

Audeoud, H. Note sur le vanillisme professionnel. Rev. Méd. Suisse Rom. **19**: 627–633. 1899.

Blaschko. Ueber die Ursache der Vergiftung mit Vanilleeis. Vrtljschr. Gerichtl. Med. Öffentl. Sanit. Berlin III. **7**: 362–364. 1894.

Brocq and Fage. Éruption érythé mateuse et papuleuse causée par la vanille. Ann. de Dermat. et Syph. **17**: 404–406. 1906.

Claverie, G. Essai sur le vanillisme professionnel. Thesis. 79 pp. Paris, 1907.

Cordero, A., and Mom, A. M. Dermatitis por vainilla. Rev. Argentina de Dermatosifilologia **27**: 461–463. 1943.

Drevon. Vanillisme. Ann. d'Hyg. et de Méd. Colon. **2**: 529–532. 1899.

Eisenheimer, A. Vanillespeise Vergiftung. Med. Klin. **9**: 251–252. 1913.

Gersbach, A. Über die sogenannten Vanillevergiftungen. Klin. Wochens. **3**: 1278–1280. 1924.

* Gigon, A. Die Bedeutung der Gewurze in der Ernahrung. Klin. Ther. Wochens. **44**: 1281–1285. 1912. Abs. in Zentbl. Physiol. **26**: 1293. 1912, and in Exp. Sta. Rec. **29**: 663. 1913.

Gourgerot, H., and Basset, A. Dermite eczémateuse professionnelle à la vanille. Im-

munisation par le travail chez les autres employés. Soc. Franç. Dermat. Syph., Bull. **46**: 1329–1331. 1939.

——— and Lortat-Jacob, E. Ecéma professionnel dû à la vanilline. Clinique (n.s.) **32**: 128. 1937.

Guéren, P. Vanillisme. Arch. de Méd. Nav. Colon. **62**: 383–393. 1894.

Hutchinson, J. An eruption caused by vanilla. Arch. Surg. London **4**: 49–50. 1892.

Kupke. Vergiftung einer Familie Vanille. Allg. Med. Cent. Zeitg. **1888**: 557.

Leggett, W. Vanilla as a skin irritant. Brit. Med. Jour. **1**(2790): 1351–1352. 1914.

Lortat-Jacob, L., and Solente. Eruption érythémateuse par vanille. Soc. Franç. Dermat. Syph., Bull. **36**: 9–11. 1929.

Maurer, A. Sur Casuistik und Aetiologie der Vergiftung durch Vanilleeis. Deut. Arch. Klin. Med. **9**: 303–315. 1872.

Papillaud, L. Empoisonnement par les glaces à la vanille. Gaz. Med. de l'Algerie **20**: 87. 1875.

Payne, R. L. Vanilla-ice poisoning. Va. Med. Monthly **3**: 612 M. 1876–77.

Pennington, C. (F.) Vanillism, an occupational ailment. Rev. Agr. Puerto Rico **33**: 313–316. 1941.

Schultz, A. Unsere gegenwärtigen Kenntnisse über Vanillevergiftung in kritischer Beziehung. Diss. 31 pp. Würzburg, 1892.

Sincke, G. E. Über Empfindlichkeit gegen Vanille. Dermat. Wochens. **99**: 1480–1481; illus. 1934.

Thompson, A. G. G. Mites and occupational disease. Jour. State Med. **33**: 419–427. 1925.

White, J. C. Poisoning by vanilla. Boston Med. & Surg. Jour. **129**: 440. 1893.

Utilization Abstract

Wood Flour. About 65,000 tons of wood flour are annually produced in the United States by mechanically pulverizing sawdust, shavings and other forms of partially subdivided wood to such fine particles that they pass through screens of 40 to 140 meshes per inch. For this purpose white pine, including Western (*Pinus monticola*), Eastern (*P. Strobus*) and sugar pine (*P. Lambertiana*), is most commonly used, but considerable amounts of spruce, hemlock and aspen, and some balsam fir, paper birch, maple, basswood, cottonwood, yellow poplar and willow are also employed. In the Scandinavian countries pine, spruce and fir are converted into the flour, and prior to World War II considerable quantities of these woods were imported from there into the United States.

Wood flour has largely displaced cork in the manufacture of linoleum where about 40% of all the flour now produced is used. For this purpose the ground cork or wood flour is mixed with an oxidized drying oil, usually linseed oil, and is then pressed to a burlap or bitumen-impregnated paper backing. With other binders it enters into the manufacture of various molded plastics.

In addition, " wood flour is used as a filler ingredient in various products either to cheapen them, or to modify their properties; as a processing agent where its texture and surface properties are used; and as an ingredient in materials where its texture combined with its burning properties are utilized ".

" Wood flour is used as a processing agent because of its absorptive, deodorizing, abrasive, and carrier properties. Its absorption of oils and greases and its carrier properties for cleansing and toxic agents in powdered form are utilized in cleaning furs and other delicate materials. It serves as an excellent deodorizer and carrier for other solids needed in only small small concentrations. It is used as a mild wet abrasive in soaps and as a dry abrasive in removing the flash from small molded plastic objects, and also polishing them by tumbling the objects and wood flour together in a rotating drum ".

" Wood flour is used in dynamite to reduce the sensitivity of the nitroglycerine to shock and as a readily combustible constituent. Light-colored wood flour is used for this purpose as it has become custom to judge the freshness of the dynamite by its light color. Darker grades of wood flour would give the dynamite the appearance of being aged. Wood flour is also used in ceramics to make the product lighter and more porous. The wood-flour particles burn completely under the kiln-firing conditions, producing innumerable small gas bubbles throughout the material ". (A. J. Stamm and E. E. Harris, *Chemical Processing of Wood, p. 264*).

American Witch Hazel—*History, Nomenclature and Modern Utilization*

The aqueous extract of witch hazel twigs has long been an American household liniment, but only three concerns manufacture it today, producing over half a million gallons annually. The more concentrated tannin-containing alcoholic extract from leaves and bark is compounded into styptic remedies.

EDMUND H. FULLING
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Introduction

Of all the household remedies for aching muscles, sore eyes and irritated skin that filled at least some American medicine cabinets a generation or two ago, no other, perhaps, has more successfully withstood the replacing competition of modern medicines than has aqueous witch hazel. Appraisals of its therapeutic value, as will be noted later, differ in the extreme, but hundreds of thousands of gallons of it are still manufactured in very modern apparatus and sold annually. After more than a century of use, witch hazel water, as a result of modern methods of distilling and merchandizing, is probably not lacking from the stock of any drug store in the United States, and considerable quantities are exported, principally to Europe, Latin America and South Africa (21). It is the most widely used and consequently the best known of nine or more commercial products manufactured from an American shrub (*Hamamelis virginiana*), the names of which, both common and scientific, have long been applied to these products. The history of these products and their current use and manufacture are the subjects of this article.

Nomenclature

Common Names. The name "witch hazel" is centuries old, occurring in English literature in connection with at least half a dozen kinds of plants and in a variety of spellings.

In the days of English archery the craftsman who made bows was known as a "bowyer", and yew wood was preferred for his trade, but an English law of 1541–1542 (Act 33, Henry VIII, c. 9, § 3) stated:

> "That everie bowyer . . . for every bowe that he maketh of Ewe, make fower [fewer] other bowes . . . of Elme, wyche hasille, ashe, or other Wood".

Although "elme" is separately specified in this decree, all authorities agree that "wyche hasille" referred to the tree that has since become commonly known as "Scotch elm" and as "wyche elm" (*Ulmus glabra* = *U. montana*), and there is no way of knowing whether "elme" and "wyche hasille" were used synonymously or whether "elme" referred to the English elm (*U. campestris*) of today. However this may have been, we do know that Scotch elm has been referred to also as "witch hazel", "wich hazel tree", "witch", "witch elm", "witch halse", "witch hasell", "witch wood", "wych halse", "wych hazel" and "wych wood", in addition to entirely different names (97). The same application to today's Scotch elm, but as "wich Hazell tree" and "witch hasell", were made, respectively, in Gerard's "Herbal" of 1597 (34) and in

an enlarged and amended edition of it in 1633. Gerard, however, recorded that the name was applied also to what he preferred to call "hornbeam" (*Carpinus Betulus*), as did other writers. Along with the forms "witchen", "witchin", "witch-wood", "witty-tree" and "wychen", as well as wholly different names, "witch hazel" has referred also to the European mountain ash or rowan tree (*Sorbus aucuparia*) (97) of Europe. *Viburnum Opulus* (74), also of Europe, and members of the African genus *Trichocladus* (99) in the family Hamamelidaceae, have been known as "witch hazel".

The origin of applying the name "hazel" to the afore-mentioned European trees appears not to have concerned any previous writer; perhaps they have regarded it as too obvious to mention that it, the name of a well known edible-nut-bearing shrub of England, was applied to those trees perhaps because of some superficial resemblance which impressed the yeomen of medieval England. The Anglo-Saxons had coined the name "haesel". The "witch" in the name, on the other hand, has been the recipient of considerable etymological speculation, and two interpretations have been proposed.

One of them associates the word with the magic powers of divination attributed in the Middle Ages to the branches of wych elm in locating witches and underground streams as well as deposits of precious metals. As late as the seventeenth century such divining rods, the "baguette divinatoire", were the subject of an elaborate treatise, and at the close of the eighteenth century the miners of Cornwall, where the superstition had taken deep root, scarcely ever sank a shaft except by direction of a wych hazel bough (36, 37).

The other interpretation, that of the philologists, is supported by no less an authority than the monumental 13-volume Oxford English Dictionary. They trace the word through several orthographic forms to the Anglo-Saxon, or Old English, "wice" and "wic" which apparently came from the Teutonic "wik", meaning "to bend". In this sense, the philologists claim, the word in its original form was applied generally or vaguely to any woody plant noted for its pliant branches. Of all the plants to which it might thus have been applied, it apparently adhered most persistently to the elm because of the latter's importance as a secondary source of bow wood.

A combination of the two foregoing interpretations explains the "witch" more satisfactorily, in the present writer's opinion, than either of them alone, for it appears quite reasonable to believe that the flexibility of certain woody plants impressed the early inhabitants of England before they associated any magical powers with them; that they therefore applied their word indicating pliability to these plants; that they later attributed divining powers to the elm; that corruption of their "bending" words ("wice" and "wic") into "witch" resulted from the similarity between the words; and that if, instead of their "bending" words, some entirely different word had been first applied, the word "witch" would not have evolved in connection with the trees to which it became applied.

Turning now to the New World, we find one of the many orthographical variations in an account of the year 1590, 17 years before the founding of Jamestown, the first permanent English colony, in 1607. This account enumerates the animals, plants and other noteworthy features in the vast territory then known as "Virginia", and contains the brief statement (45):

> "Maple, and also Wich-hazle, whereof the inhabitants use to make their bowes".

It is impossible to determine whether this use of the name referred to the true American witch hazel (*Hamamelis*

virginiana), the branches of which may have been used by the Indians as bows, or to the American elm, possibly also used in that manner and resembling the elm of England, with which the writer of that early account presumably was familiar and which, as we have already noted, was a secondary source of bow wood in the Old World. The question is all the more confounding because there is mention also of "elme" on the same page.

Nearly 200 years later a certain military man, given to recording his extensive observations but not versed in plant lore, used our present day spelling and stated that (23):

> "Witch hazel . . . is covered early in May with numerous white blossoms. When this shrub is in bloom, the Indians esteem it a further indication that the frost is entirely gone, and that they might sow their corn".

Since the blossoms of the American witch hazel are yellow and open in autumn, it is impossible to determine where this author's error lay.

The preceding two instances suggest that in the American colonies, too, the name may have been used, at least at first, in connection with any woody plant having supple branches. Later, however, it was limited to the true American witch hazel, the earliest record of which, so far as the present writer has been able to find, is a brief note of equivalency between the name "witch hazel" and the generic name "*Hamamelis*" in 1760 (61); that was 18 years after Linnaeus, as will later be noted, established the genus and seven years after he published the specific name "*virginiana*". It is reasonable to presume that such association long antedated the record of 1760, but why the name, especially the

FIG. 1. Witch hazel in foliage.

"witch" part of it, became attached to the American shrub, so utterly different from the witch hazel, or wych elm, of England in habit and fruit though not so much in foliage, is not easy to answer. Two or three solutions have been proposed.

One of them has it that "hazel" was applied because of a similarity in foliage, general habit and young fruits between the American shrub and the hazel (*Corylus*) of England, and that the witch-like divining qualities which at that time were associated with the European hazel, as with the wych elm, were attributed in the minds of the colonists to the new found shrub because of the similarity in other respects. Another interpretation says that the early American settlers saw something in the foliage or habit of the American shrub suggestive of the English witch hazel, and that "they transferred the old English name to the newly-discovered American shrub, being influenced probably by the same love for the homewords which prompted them to call the red-breasted American thrush a robin and the marsh marigold a cowslip" (37). The point is that the difference between these two birds, and two plants, is as great as between the American and English witch hazel, but that the similarities which do exist were sufficient to impress those who transferred the names. A third explanation (86) suggests that use of the twigs in locating underground water and deposits of metals came first (from the Indians or English charlatans?), and that the application of the old English name resulted. The reader may take his choice, and the present writer has no preference, but he certainly is disdainful of the following imaginative explanation coupled with a definite inaccuracy regarding fruiting time (7):

> "Superstitious folk gave the witch hazel plant its name in awe of supposed powers of a plant that blooms late in autumn and ripens its fruits in spring"!

Other, less well established, names have been applied to the American witch hazel, and some of them may still be in use in various parts of the shrub's natural range of distribution. Each of them very likely had a restricted origin and usage as some resemblance or characteristic of the shrub impressed the local inhabitants. Among them are "winter hazel", "snapping hazel", "winterbloom", "spotted alder", "tobacco wood" and "pistachio".

It is recorded, on the other hand, that "witch hazel" has been applied also to the American shrub *Fothergilla Gardeni* (74, 97) and in Labrador and Newfoundland to sweet birch (*Betula lenta*) and yellow birch (*B. lutea*) (97) [1].

To recapitulate, "witch hazel" as a name has been used in connection with the following woody plants:

Hamamelis virginiana of eastern North America, the only American application today, at least of widespread usage.

Ulmus glabra of Europe; commonly so applied today along with the designation "Scotch elm".

Carpinus Betulus, the hornbeam of Europe.

Sorbus aucuparia, European mountain ash.

Viburnum Opulus, the European cranberry-bush.

Trichocladus spp., shrubs of southern and tropical Africa.

Fothergilla Gardeni of the southeastern United States.

Betula lenta and *B. lutea*, sweet and yellow birch, respectively, in Labrador and Newfoundland [1].

Scientific Names. The earliest published Latin name that can be traced as applying to American witch hazel is the pre-Linnean polynomial "Pistacia

[1] In giving the two applications to birch, Van Wijk (97) cites Bergen (18) as authority, but the present writer was unable to find them in any of the six parts of Bergen's catalogue.

nigra Coryli folio "[2], a name obviously based, as the common name may have been, on the hazel-like or *Corylus*-like nature of the leaves. It was used by John Banister, a missionary in the British colony of *Virginia*, and was printed in London in 1688 in Ray's "Historia Plantarum" (82) as part of a list of Virginia plants sent by Banister in 1680 and supplemented in 1687 with a publisher's note separating them. According to Sargent (86), this is the earliest known published catalogue of Virginia plants.

In 1742 Linnaeus established the genus *Hamamelis* (64) on the basis of the American shrub and by appropriating therefor a Greek botanical name which at the time was already 2,000 years old. Hippocrates had used the name four centuries before Christ in connection with the medlar (*Mespilus germanica*), an apple-like tree of southeastern Europe and other parts of the Old World. The name is composed of two Greek roots, *hama*, meaning "at the same time" or "together", and *melon*, meaning "fruit", or "apple". The combination was applied to the medlar because it blossoms at the same time as the apple in Greece. It is very apparant that Linnaeus, who was especially concerned with flowers as a basis for classification, was impressed by the fact that in his new American shrub the blossoms appeared along with mature fruits of the previous season and that he therefore selected the ancient Greek name for a very appropriate application. Two years later we find this generic name in use by at least one American scholar (39). In 1753 Linnaeus proposed the presently recognized specific name (65), *Hamamelis virginiana*, the species part of which has at times been spelled "*virginica*". In publishing the name, Linnaeus cited that used by Plukenet, and therein lies the evidence that Plukenet's and, in turn, Banister's polynomials applied to the American witch hazel. In subsequent years one other American species (*H. vernalis* Sarg.) became recognized in south-central United States, and four or five in China and Japan. *H. vernalis* differs from *H. virginiana* by having reddish petals and by flowering in winter or early spring instead of autumn.

[2] This is contrary to a statement of Sargent in 1893 (86) and to as recent a writer as Peattie in 1950 (78) who very likely relied on Sargent. Sargent credits Banister with having first "noticed" the plant, not with having named it; instead, he says that the earliest name to appear in print was "Pistachia *Virginiana* nigra Coryli foliis *D. Banister*" in Plukenet's "Almagestrum Botanicum", published in 1696 (80). Sargent cites Ray's work, in which Banister's polynomial appeared, but it is doubtful that he saw it because it is obvious from a comparison of Ray's and Plukenet's works that Plukenet took Banister's name for the plant from Ray's work, with a slight change in spelling, and inserted the two words "*Virginiana*" and "*Banister*", even distinguishing them by italics.

Characteristics and Natural Distribution of American Witch Hazel

American witch hazel is a shrub attaining heights up to 25 feet, or tree-like stature up to 35 feet, and is native to North America from New Brunswick and Nova Scotia in eastern Canada westward to southeastern Minnesota, eastern Iowa and eastern Texas, and south to northern Florida, central Mississippi and northern Louisiana. In the Appalachians it ascends to 4,000 feet elevation.

In addition to its very characteristic wavy-margined leaves, two features are equally distinctive but not so readily observed. One is that the blossoms, consisting of four narrow, strap-shaped, twisted, yellowish petals, appear from October to December in the northern woods, not only after the witch hazel has shed its leaves but also at a season when nearly all deciduous trees and shrubs of the area are destitute of foliage and dormant. Witch hazel is thus the last of our native plants to flower in the calendar year, at least in the northern woods,

and may at times be found in bloom as late as the Christmas season. In the southern parts of its range the shrub may flower from January to March.

The second feature is that at the time of flowering every year, the fruits of the previous year attain maturity and burst open, at times with sufficient force to eject their two seeds to distances which have been measured up to over 30 feet. In most cases the dispersal very likely falls far short of this dissemination, attained only under ideal conditions that develop the necessary tension within the drying fruit.

Use by the American Indians

According to some American medical botanies of the nineteenth century (42, 55, 69, 81) and later works (e.g., 33, 41, 101) probably based on those earlier writings, the American aborigines boiled the stems of witch hazel and used the resultant liquid, known to some of them as "magic water", as a relief for piles, hemorrhages, bruises, cuts, scratches and other injuries; they made poultices of it for painful swellings, tumors and external inflammations; and sore eyes were also treated. Regarding this last mentioned application, the following is from a letter in the year 1744 to the Dutch botanist, Gronovius of Leyden, from Dr. Colden who, among other accomplishments, was at one time governor of the province of New York (39):

> "As you seem to be pleased with my communicating the use of any plants discovered in this country, I shall tell you what I learned of the use of the *Hamamelis* from a minister of the Church of England who officiates among the Mohawk Indians. He saw an almost total blindness, occasioned by a blow, cured by receiving the warm steam of a decoction of the bark of this plant through a funnel upon the place. This was done by direction of a Mohawk Indian, after other means had for a considerable time proved ineffectual".

It is to be noted in this excerpt that Colden was acquainted with Linnaeus' generic name for the shrub two years after that name had been established, and that the efficacy of the treatment related in the account is carried over in the inclusion of *Hamamelis* in eye lotions of today. Confirmation of this early American use lies in a statement of the Swedish botanist-explorer, Per Kalm, in 1751 when he wrote (60):

> "*Hamamelis*. Fumes from a decoction of the bark are incomparable in treating eye diseases. With them I saw a savage cure a boy who had been almost stone blind for a half a year".

Two ethnobotanical studies of relatively recent years (91, 92) reveal the use of witch hazel by the Menomini, Potawatomi and Stockbridge Indians of Wisconsin. The first of these tribes formerly ranged over northern Wisconsin and adjacent upper Michigan, two areas separated along about half of their boundary by the Menominee River. In 1923, survivors of the tribe numbered about 1745. Members of the tribe, as indicated by the native name "Menominee", were the so-called "wild rice men" because of their great use of the wild rice (*Zizania aquatica*) which grows abundantly in their country. This utilization has been described in a previous issue of ECONOMIC BOTANY (April–June, 1952). Witch hazel was known to them as "pisewá tik" and "pisă-kiwus", and twigs of the shrub were steeped in water to make a decoction for rubbing on lame backs or on the legs of participants in athletic games in order to limber them. They are said to have learned this use from the neighboring Stockbridge Indians, also living on the Indian reservation near Green Bay, Wisconsin, and representing the Mahican tribe which formerly occupied most of the Hudson River Valley but which dwindled to survivors gathered in 1736 into a mission in western Massachusetts which two or three years later became the town of Stockbridge. Here they acquired their

present name, and by 1829 the remnants of the tribe were settled on the Green Bay reservation. On the basis of these records it may be concluded that liniment use of witch hazel decoction was originally widespread among the Indians of New York and adjacent areas but was not in vogue in the North Central States until contact between the tribes had been established by virtue of their becoming neighbors on an Indian reservation. In addition, the black seeds of witch hazel, known to the Menominee as "mêgîse", were used by them as sacred beads in their medicine ceremony.

FIG. 2. Witch hazel shrubs in autumn, denuded of foliage but in flower. (*Courtesy New York Botanical Garden*).

The Potawatomi of the Green Bay, Wisconsin, region knew witch hazel as "bwaoté it" and "paga nîmîg", and

employed it as one of their remedies in sweat baths by placing twigs in water and heating the latter with hot stones to produce steam for bathing sore muscles.

The Ojibwa, or Chippewa, Indians formerly held extensive territory about the upper Great Lakes, in Michigan, Minnesota, Ontario, Manitoba and adjacent regions. To them witch hazel was known as "nsakemizins", and the inner bark was used as an emetic, especially in poisoning. As among other tribes, the twigs were steeped to produce a lotion for any skin trouble and as an eye wash (35).

At least one author (24) concerned with plants used by the American Indians either overlooked witch hazel or regarded its use by them as insufficient to have merited inclusion of it in his study. The former explanation is the more plausible.

FIG. 3. Drawing of flowers and fruits of witch hazel against a background of foliage. (*From Sargent, C. S. Silva of North America. Courtesy Macmillan Book Co.*).

Early Use by the White Man

Medical. The foregoing Indian uses of witch hazel may have been taken over in isolated areas by the white settlers of the eighteenth century, and they very likely were to a greater degree in the early nineteenth century. Recognition by the embryonic American medical profession, however, was not so rapid, and this may indicate that use by the Indians was not impressive. The first medical school in what was later to become the United States was established at the University of Pennsylvania in 1765, and in 1768, Adam Kuhn, a pupil of Linnaeus, was there appointed the first professor of materia medica and botany in the United States. At that date, it appears, witch hazel had not yet been accorded medical recognition by the physicians of the time, for it was not mentioned in a work of 1798 (15), directed particularly toward formulating a materia medica of the United States, or in others of several years thereafter (15–17, 20, 50).

The earliest medical mention of witch hazel which the writer has found is in a book of home remedies published in 1816 (22), eight earlier editions of which do not appear to mention the shrub [3]. Herbalists of the time, however, must have been promoting use of the shrub, for 12 years later Rafinesque (81) referred to it as a "sedative, astringent, tonic, discutient", adding that the Indians greatly valued it and that it was:

> "much used in north by herbalists. Bark gives excellent topical application for painful tumors and piles, external inflammations, sore and inflamed eyes, etc. in cataplasm or poultice or wash. A tea is made with the leaves, and employed for many purposes, in amenorrhea, bowel complaints, pains in the sides, menstrual effusions, bleeding of the stomach, etc. In this last case, the chewed leaves, decoction of the bark or tea of the leaves, are all employed with great advantage. A strong infusion is given in injection for bowel complaints. It is said to be a mild yet efficient astringent in all cases".

Rafinesque then listed ten other plants which, he claimed, might be used as substitutes.

In a medical botany of 1833 (55), those who read such erudite works at the time were informed that:

> "The bark and leaves are slightly bitter and very astringent. The leaves are a most valuable article of medicine, as an astringent tonic and styptic. They may be employed in tea for bowel complaints, bleeding at the stomach, lungs, and all other internal hemorrhages; and in snuff for bleeding at the nose; and no doubt might be advantageously applied to wounds to stop the effusion of blood. As a styptic to check internal bleeding, the witch hazel, perhaps, is among the best articles known".

A few years later, in 1847 (42), a medical student was informed that the bark was

> "applied to painful tumors and external inflammations, chronic ophthalmia, &c., in the form of a decoction or cataplasm. A tea of the leaves is used as an astringent in bowel infections, and haemorrhages".

This same author conveys the impression that use of witch hazel at his time was not widespread and that not much was known about it, for he noted that "it is in use in some parts of the country in domestic practice" and that "this article seems to have some peculiar powers, and deserves a careful investigation".

An authority of 1884 (58) stated that, while the U. S. Pharmacopoeia directed that leaves collected in autumn alone be used, he believed this to be a mistake because in his personal experience the bark of young branches was more efficient. He mentions its use for internal bleeding and "topically in hemorrhoids and varicose veins, bruises, sprains, etc.".

[3] The earlier editions, going back to 1796, do not have indices to the plants mentioned, only to diseases, and it is unlikely that they contain mention of witch hazel because the edition of 1816 does not prescribe the plant; it only describes the bush and states that it was said to possess medicinal virtues.

The virtues of witch hazel were especially extolled, particularly in connection with consumptive bleeding, in an article of 1848 (30) which contained, in addition, the following prescription:

> "R. White-hazel bark. White oak bark, the inner part. Sweet apple tree bark, of each three handfuls. Water, three quarts. Boil down to one pint—strain; add lard half a pound, simmer out the water, stirring it continually, before and after removing it from the fire, till it cools. It forms a brick-coloured, anodyne, astringent ointment—admirably adapted to the cure of hemorrhoidal tumors".

Another report of the same year (6) quoted extensively from the foregoing account of controlling consumptive bleeding, added substantiating evidence and bemoaned the fact that witch hazel was "barely noticed in the U. S. Dispensatory, and by Rafinesque, Lee, Barton, Griffith, Williams, etc.".

Scientific information in the mid-nineteenth century was not so rapidly disseminated as today, but it is difficult to regard that situation as responsible for the great skepticism regarding the efficacy of witch hazel expressed in 1857 by Asa Gray, the botanical scholar of Harvard University. Book reviews had their place in scientific literature at that time probably as much as today, and as part of a lengthy review of Henfrey's recently published book (47), Gray wrote the following comment as he chewed the leaves and bark of the shrub (40):

> "We were surprised at the statement that the bark and leaves of *Hamamelis Virginica* 'are astringent and contain an *acrid volatile oil*'. We trace it back to Lindley's *Vegetable kingdom*, p. 784, and find: 'The kernels of *Hamamelis Virginica* are oily and eatable. The leaves and bark are very astringent, and also contain a peculiar acrid esential oil'; and this, we find, comes from Endlicher's *Enchiridion*. How did this bland and inert plant acquire such a reputation? Dr. Barton, who has figured it, says nothing of its possessing any sensible properties or useful qualities at all, except its use for divining rods; nor do Pursh, Bigelow, Elliott, Darlington, &c., allude to any popular reputation of such qualities. No sign of any essential oil is to be detected in the foliage, and prolonged mastication of the leaves and bark while we write yields not the slightest trace of acridity and hardly any of astringency; no more, certainly, than a Beech-leaf. We never heard of the seeds being eaten; and as they are 'about the size of a grain of barley', or not much larger, and have a thick bony coat, they are not likely to become an important article of diet".

In support of his skepticism, Gray continued as follows:

> "After some search, we find the source of these extraordinary statements in the *Medical Flora* of the excentric Rafinesque. He says the seeds are called Pistachio nuts in the Southern States, are rather oily and palatable, etc., but he neglects to mention their size. He adds, 'the bark and leaves are somewhat bitter, very astringent, leaving a sweetish pungent taste. The smell is not unpleasant. It has not been analyzed as yet, but probably contains tannin, amarine, extractive, and an essential oil'. To all this, Endlicher, on the strength of 'the sweetish pungent taste', has added the acridity; and so one of the blandest of shrubs gets a world-wide and wholly factitious reputation for active medical qualities and esculent seeds; and even Dr. Griffith, who must have known the shrub, has been induced to give it a place in his Medical Botany".

The interesting feature about the foregoing review by Gray for the reader today, apart from its historical interest, is that, in citing Rafinesque, Gray omitted that part of Rafinesque's account which described the medical uses of witch hazel and which we have quoted on a preceding page. The reader may decide whether the omission was accidental.

The foregoing authorities did not provide directions for preparation of witch hazel potions, but we do find one as of 1887 (69):

> "The bark of the young twigs and roots is chopped and powdered to a pulp and weighed, then two parts by weight of alcohol are taken, the pulp mixed with one-sixth part of it, and the rest of the alcohol added; after having stirred the whole well, pour it into a well-stoppered bottle, and let

stand eight days in a dark, cool place. The tincture, separated by decanting, straining and filtering is by transmitted light of a deep yellowish-brown color ".

In addition to the preceding, medicinal mention of witch hazel is to be found in a few other nineteenth century American publications (e.g., 2) as well as a few of European authorship (e.g., 13).

Other Early Uses. The other nineteenth century uses of witch hazel were utilization of the twigs as diving rods, and possibly consumption of the seeds as food.

If we believe that the American aborigines employed the twigs of *Hamamelis*, as already suggested, to locate subterranean water and mineral deposits, we have one basis for the origin of the common name. If, on the other hand, we prefer to think that the English settlers imputed the virtues of wych elm along with bestowal of the designation " witch hazel " to the American shrub, it follows that the Indians may have learned the trick from the white man. Whichever way it went, the twigs were so used in the eighteenth and nineteenth centuries by both red and white adepts in the occult arts, and some of them very likely profited handsomely by selling their services to the credulous. The earliest such account is that of the military explorer and writer Carver, which, as previously noted, may or may not have referred to the true American witch hazel. Skeptical of the application, he wrote (23):

" The Witch Hazel . . . . It has been said, that it is possessed of the power of attracting gold or silver, and that the twigs of it are made use of to discover where the veins of these metals lie; but I am apprehensive that this is only a fallacious story, and not to be depended on; however that supposition has given it the name of witch hazel ".

The procedure of divination has often been described and undoubtedly varied considerably in the ceremonious details observed. One account at the beginning of the present century states that (37):

" The 'divining rod', or 'wishing rod' or 'finding stick' is a Y-shaped section of a branch, with all its leaves removed. It must be new wood and it must have grown

FIG. 4. Blossoms and opened fruits of witch hazel. (*Courtesy New York Botanical Garden*).

> upon the tree in such a position that the rising and setting sun looked between the prongs. The two ends of the Y must be held one in each hand, with the point projecting straight forward. The hands must be seven or eight inches apart with the knuckles down and the thumbs outward. If the rod is in the right hands, as soon as the bearer passes over a vein of metal or an underground spring it will move on its own accord and will twist over till the foot of the Y points toward the ground".

Fifty years later a very recent writer, after considering the relationship of the words "witch", "wych", "wick" and "wicken", has the following to say (78):

> "However all that may be, it is certain that, in early days in America, witch hazel was used in local witchery, to find water or even mineral deposits. You took a forked branch, one whose points grew north and south so that they felt the influence of the sun at its rising and setting, and you carried it with a point in each hand, the stem pointing forward. Any downward tug of the stem was caused by the flow of hidden water or the gleam of buried gold. And if there are people still who believe in water-witching, theirs is one of the most harmless and pleasing of fallacies".

The author might have added "incredible" and "puerile" to his appraisal of this fallacy.

Use of witch hazel as a source of food is less well established. One writer of 1846 (63) referred to the seeds as being oily and edible, and another, in 1875 (14), stated that they were actually used as food, but Asa Gray, as previously noted, doubted these reports. More recently it was reported that the Iroquois of Canada use a decoction of the leaves, sweetened with maple sugar, as a tea with their meals (98).

Early Commercial Use

According to one account (67), in the early 1840's Theron T. Pond of Utica, New York, found the Oneida Indians in the neighboring territory used a "tea", made by their medicine man by boiling witch hazel in an iron kettle, for treating burns, boils and all kinds of wounds. Impressed by their faith in the efficacy of their "tea", Pond formed a sort of partnership with the Indians to produce the material commercially, and in 1848, under the impressive name "Golden Treasure", the extract was marketed. Manufacture was continued after Pond's death, but the name was changed to "Pond's Extract", and as such it was sold for many years thereafter. After changes in management during those years, manufacturing operations were moved to Chester, Conn., about 1875, and there began present day steam distillation of the preparation; the business was conducted in New York City.

From another account (8) we learn that Charles Hawes, an early nineteenth century missionary in New England, was versed in the chemistry of that day and by various experiments claimed to have demonstrated the medicinal qualities of witch hazel extract. He thereupon began manufacturing and distributing the material in his neighborhood.

Next in the story was Dr. Elmer Whittemore of New London, Conn., who left that city and opened a drug store in Essex, Conn., adding witch hazel extract as "Hawe's Extract" to his stock, but later changing the name to "Golden Treasure", most likely because the preparation under that earlier name had already acquired recognition and favorable repute. Trade names apparently were not yet copyrighted. Dr. Whittemore presumably prepared the extract himself, at least at first, but he soon approached Thomas N. Dickinson, Sr., of Essex to assist him in the new industry. That was in 1866, or thereabout, the year in which the witch hazel industry is regarded as having been established on a commercial basis. Mr. Dickinson had been a successful manufacturer of Civil War uniforms and at the time of his becoming associated with Whittemore was a retired Baptist minister. This association lasted several years, and

during it the Reverend conceived the idea of distilling and distributing the distillate to the public, not merely as an enterprise of individual druggists who might manufacture it themselves, but in bulk through the medium of the drug trade. In the early 1870's, accordingly, he began brewing and distributing the extract himself in Essex, and thereby began an association of a family name with a particular plant product through four generations to the present, almost to the exclusion of other names. With headquarters in Essex, he operated

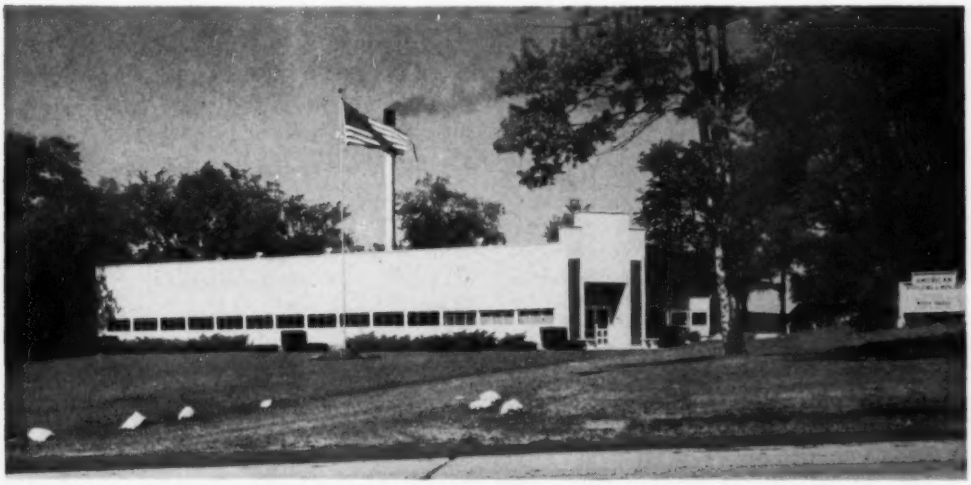

FIG. 5. Witch hazel extract manufactory of the American Distilling and Manufacturing Company, East Hampton, Conn.

branches and distilleries in Middlesex, New London, New Haven and Hartford Counties (46).

Associated with the Reverend in his independent enterprise were two sons who, subsequent to the father's death in 1900, in turn went into the manufacture of aqueous witch hazel independently, one in Mystic, the other in Essex, Conn. From 1888 to the time of his death in 1938, the Mystic son, Thomas N. Dickinson, Jr., operated eight witch hazel distilling plants in various localities in Connecticut, distilling also oil of birch. One of the plants was in Ledyard, and "Ledyard Witch Hazel" is still being marketed by the T. N. Dickinson Co. of Mystic which this year, under the presidency of T. L. Dickinson, son of "T. N., Jr.", is celebrating its sixty-fifth year. The son who set up business in Essex is today represented by his grandson, E. E. Dickinson III, who directs the E. E. Dickinson Company in Essex and who thus represents the fourth generation in the Dickinson family to manufacture and market this product. The Essex factory today is an impressively modern institution, consisting of four principal buildings for distilling, storage, machine shop and packaging operations, respectively. Ten or a dozen stills occupy the first of these, and the huge storage facilities of glass-lined tanks, each holding tens of thousands of gallons, is strikingly indicative of the demand which still exists for an old American household remedy. Equally as impressive of this volume are the facilities for retail bottling and for bulk distribution in paraffin-lined oak barrels.

In the early years of the industry, subsequent to its first effective promotion by the Reverend Dickinson, at least

a dozen other concerns competitively entered the field [4]. In 1906 the E. A. and W. E. Childs Company began manufacturing witch hazel as well as several other plant products in East Hampton, Conn. In 1941 the American Distilling and Manufacturing Company purchased the E. A. and W. E. Childs Company, and has since been producing only witch hazel extract. A third distillery has been operated in Long Hill, Conn., since 1951 by United Witch Hazel Distillers, but by at least one other concern for several years previous. The Essex, East Hampton and Long Hill manufactories are thus the only witch-hazel manufacturing concerns today, and their procedure of operation is described later in this account. Of the 12 companies listed today under "witch hazel" in three directories of manufacturers (28, 56, 93), only these three are actual manufacturers of the product from the raw material, and inquiry by correspondence has not revealed any not listed in those directories. Additional manufacture on a small scale may be carried on elsewhere, as by a drug concern compounding the extract into its own products or as was done some years ago by Dr. Otto Raubenheimer in his drug store in Brooklyn, N. Y. (103). Such manufacture would be small in quantity and of only local use.

Present Day Collection of Raw Material

Witch hazel bushes are cultivated only for ornamental purposes. All material gathered for industrial utilization is collected from wild plants in two rather restricted areas when compared with the entire natural range of distribution.

One of those areas covers Connecticut and at times adjacent parts of Massachusetts and Rhode Island, furnishing material that is used only in the manufacture of aqueous witch hazel. In autumn, after their leaves have fallen and their flowers have begun to appear, the bushes are cut nearly to the ground in various parts of this region, either by the owners of the land on which they are growing or by agents of the witch hazel companies who have previously contracted with the owners at agreed prices for the right to do so. The smaller twigs are the more valuable, and stems over two inches in diameter are not acceptable, because the extractable components are only in the bark and at that size the percentage of valueless wood is so great as to render extraction unprofitable. During the history of the industry and according as has been most practical in view of distances, vehicular equipment and other factors, the cut bushes have been brought to the factories by the land owners, or by them to collecting points where company agents have called for them, or have been brought in by the agents of the companies who have done the cutting. Before the cut bushes can be used they must be chopped by machinery into pieces up to three inches in length, and in years gone by, when modern highways did not provide accessibility to the woods, this chopping was often performed at the collecting sites by portable machinery, thus reducing the bulkiness of brush to be hauled from the woods. Today, modern facilities render it more profitable to carry out the chopping operations at the factories. Collecting activities continue several months in autumn, sometimes well into the winter and spring, but the chopping is performed only as the brush, stored outdoors at the factories, is consumed. The

[4] Some of these were (27): Puritan Witch Hazel Co.; American Witch Hazel Co., Chester, Conn.; H. M. Bailey & Co., Guilford, Conn.; Gould's Witch Hazel Co., Vermont; Mystic Distilling Co., Mystic, Conn.; Clift Bros., Mystic, Conn.; American Chemical Co., Philadelphia, Pa.; E. A. and W. E. Childs Co., East Hampton, Conn.; Hoyt Bros., Long Hill, Conn.; Pennsylvania Witch Hazel Co., Tunkhannock, Pa.

cut bushes readily regenerate, and in five to ten years, areas may be re-harvested.

The other collecting area is in the mountainous regions of the southern Appalachians in Virginia, West Virginia, North Carolina, Tennessee and Kentucky. Here the bushes are not cut down, but fresh leaves are plucked from them and bark stripped from the branches for manufacture into pharmaceutical and cosmetic products.

The gathering of leaves is performed for the most part in summer and the early fall months as their sought-for tannin content increases, but some collecting is reported (100) to begin in spring. The leaves are then dried by exposure to air, preferably in shade so that their green color will be retained. These operations are carried on by native gatherers in the mountains who then bring the dried material to dealers for inspection, purchase, baling in burlap bags and storage in warehouses to await disposition to utilizing industries. Some of this harvest goes into American use but most of it is exported to Europe to be used very likely in similar ways and also as a bouquet in certain French wines.

Bark is collected in all seasons. The major portion of it, however, is peeled from standing bushes in warmer weather of spring and summer when the sap is up and the bark consequently peels easily. In colder months, when peeling is not so easy, it is cut from freshly harvested branches, and the remaining refuse used as fuel.

In the aqueous witch hazel industry, as developed in Connecticut, the collectors of brush sell directly to the distilling plants; there are not any middlemen dealers. In the Appalachian trade in leaves and bark, on the other hand, there are intermediaries between collectors and ultimate utilizers, and their trade is considerable, for, as "botanical supply houses", they deal in a great variety of raw plant material needed by the cosmetic and pharmaceutical industries. Foremost among these supply houses are S. B. Penick Co. of New York with warehouses in Asheville, N. C., and Newark, N. J.; R. T. Greer & Company of Marion, Va., and Pikeville, Ky.; Greer Drug Company of Lenoir, N. C.; and the Wilcox Drug Company of Boone, N. C.

Products

Nine products of cosmetic or pharmaceutical value are today manufactured from the twigs, leaves or bark of witch hazel collected in New England or farther south in the Appalachian mountainous regions. Aqueous witch hazel is the most widely known and extensively used of them; the others are prepared in relatively small amounts and are utilized only by compounding manufacturers. Four of the products, in the terminology of the U. S. Pharmacopoeia [5], the National Formulary [5] and the U. S. Dispensatory [5], are:

a) "Hamamelis Leaf". Known also as "Hamamelidis Folium" and as "witch hazel leaves". Marketed as "Unground Hamamelis Leaf" and as "Powdered Hamamelis Leaf". Official in U. S. Pharmacopoeia from 1882 (U.S.P. VI) to 1916 (U.S.P. VIII), omitted since 1916 (U.S.P. IX); in Na-

[5] A drug listed in the U. S. Pharmacopoeia and therefore "official" in that publication is recognized by the medical profession as possessing definite therapeutic value. Many other drugs are also in medical use but not of such high repute; they may be listed in the National Formulary and are then said to be "official" in that work. The National Formulary, furthermore, prescribes the method of manufacturing drugs in some detail, and reputable manufacturers are diligent in observing these directions as standards of quality. The Dispensatory is an encyclopaedic volume dealing with all known drugs, "official" as well as "unofficial", but does not establish any standards except by separating all drugs into these two categories on the authority of the Pharmacopoeia and the National Formulary.

tional Formulary from 1916 (N.F. IV) to date (N.F. IX).

b) "Hamamelis Leaf Fluidextract". Known also as "Fluidextractum Hamamelidis Folii" and as "witch hazel fluidextract". Official in U. S. Pharmacopoeia from 1882 (U.S.P. VI) to 1916 (U.S.P. VIII), omitted since 1916 (U.S.P. IX); in National Formulary from 1916 (N.F. IV) to date (N.F. IX). Made by macerating a weighted amount of coarsely ground leaves in a menstruum of alcohol and glycerine for 48 hours, then percolating and subsequently diluting the concentrated percolate with additional alcohol so that approximately one gram of crude drug, i.e., of ground leaves, is represented in every cubic centimeter of finished product which is marketed as a liquid. Percolation according to the British Pharmacopoeia is accomplished with 45% alcohol alone.

c) "Hamamelis Bark". Known also as "Hamamelidis Cortex" and as "witch hazel bark". Official in the U. S. Pharmacopoeia from 1905 (U.S.P. VII) to 1916 (U.S.P. VIII), omitted since 1916 (U.S.P. IX); never in National Formulary. Marketed as thin pieces, three to four inches long, pinkish on the inside.

d) "Hamamelis Water". Known also as "Aqua Hamamelidis", "distilled witch hazel extract", "distilled extract of witch hazel" and, simply and most commonly, merely as "witch hazel". Official in the U. S. Pharmacopoeia from 1905 (U.S.P. VII) to 1926 (U.S.P. IX), omitted since 1926 (U.S.P. X); in National Formulary from 1888 (N.F. I) to 1905 (N.F. II), omitted from 1906 (N.F. III) to 1936 (N.F. V), readmitted from 1936 (N.F. VI) to date (N.F. IX). This is the most widely known product, the manufacture of which is later described in some detail.

Only the four preceding products are listed in the latest trade directories (4, 29). The others are:

e) Powdered extract of Hamamelis. Made by macerating and percolating coarsely ground leaves with alcohol, recovering most of the alcohol from the extract and then evaporating in a vacuum drier to a powder, every gram of which represents about four grams of crude drug (89).

f) Semi-solid extract of Hamamelis. Made by partially evaporating an alcoholic percolate of coarsely ground leaves to a semi-solid state (89).

g) Hamamelis solution. Made by macerating leaves in water and alcohol and then obtaining a distillate (85).

h) Tincture of Hamamelis. Made by macerating bark in alcohol, percolating and then diluting with water (85).

i) Hamamelin. A concentrated alcohol-soluble dry extract obtained as a precipitate by addition of water to a fluid alcoholic extract of powdered leaves (3, 33, 89).

Modern Manufacture of "Witch Hazel"

All commercially produced aqueous witch hazel, or Hamamelis water, commonly known merely as "witch hazel", is manufactured, as already stated, by only three concerns, all in Connecticut—The E. E. Dickinson Company, the oldest, at Essex; the American Distilling and Manufacturing Company, at East Hampton, presently "the largest producer of witch hazel, N. F., in the world—selling in bulk only"; and the previously mentioned distillery at Long Hill.

Processing. The National Formulary IX prescribes the manufacture of this product thus:

> "After macerating a weighted amount of recently cut and partially dried dormant twigs of *Hamamelis virginiana* for 24 hours with twice their weight of water, distill not more than 850 cc. of distillate for each 1,000 gm. of twigs taken, add 150 cc. of alcohol to each 850 cc. of distillate, and mix thoroughly".

In carrying out these directions, subsequent to chopping the brush as previously noted, the manufacturing process extends from late autumn until the following spring or early summer. After this period the manufactories are idle, except for cleaning and shipping operations, but during the busy season the operational procedure in general is as follows:

FIG. 6. Percolating apparatus of Eli Lilly & Co., Indianapolis, Indiana, used for preparing Hamamelis and other plant extracts.

a) Weighted amounts of chopped brush are macerated in large steam-jacketed cookers and cooked in water for seven to ten hours, depending on various factors.

b) Steam from the cookers, containing the extracted volatile components of the brush, is led to a vapor-mixing chamber for the purpose next described.

c) Alcohol must be added to the distillate as a preservative against mold, and years ago, when it was economically feasible to do so, pure alcohol was added to the distillate as a separate operation after the distillate was condensed in a condensor. In recent years, however, since a high Federal tax on alcohol has been in force—about $24 per 60¢ gallon—the manufacturers use tax-free denatured alcohol, from which they first remove the denaturant by distilling off the alcohol. In order to prevent unscrupulous operators from abusing the privilege of removing a denaturant so as to obtain tax-free pure alcohol, Government regulations do not permit purification of the alcohol as a separate operation and then addition of the alcohol to the witch hazel distillate, but require that both operations be

carried out separately and simultaneously through a sealed system so that the alcohol may not be obtained in its purity as a separate product. This is accomplished by leading the distilled alcohol vapor and the distilled witch hazel vapor separately into a vapor-mixing chamber which in turn leads to a condenser where the two vapors are condensed together.

d) By proper control of the quantity and thickness of twigs, water and alcohol used, and with suitable mixing of these ingredients, a final product is obtained, which, in conformity with the standard of the National Formulary, contains, per gallon, the extract from about eight and one-third pounds of brush and has an alcoholic content of 14% to 15%.

According to the U. S. Dispensatory, the distillate originally obtained with fresh water is used to macerate a fresh portion of twigs, from which another distillate, supposedly with a greater concentration of the desired ingredients of the twigs, is secured. The second distillate may be used to macerate a third charge of twigs, and the third distillate for a fourth charge. On the label of the marketed product each distillation is represented by an X. An extract obtained by thus employing the same water on four successive batches of twigs is marked XXXX and contains the greatest concentration of extractable material from the twigs that it is possible to obtain. Careful consideration of the implications in this report present several conflicts which it is difficult to reconcile, and the author has been informed (21) that there no longer is any such "double distilling", if there ever was, and that manufacturers now are permitted to label their product, for some inexplicable reason, with XX but no more, even though there be no actual second distilling. The real control of concentration of extractable material in the distillate is by using as much of small diameter twigs as possible, for, the smaller the diameter, the less is the percentage of wood, or "pulp" as the distiller prefers to speak, and the greater the percentage of bark which contains the extractive.

e) The final product is packed in bottles for retail trade, or in paraffin-lined oak barrels for bulk sales, or is stored in wooden vats or in glass-lined steel containers of huge capacity.

Output. Production figures concerning annual output of witch hazel have not heretofore been available, but the amounts may be calculated on the basis of the quantities of specially denatured alcohol allocated for the purpose. Though the actual manufacturing content may be a few tenths of one percent higher to take care of evaporation, aqueous witch hazel is marketed as a 14% product, and on that basis the annual amounts produced in a recent 13-year period are as follows (95):

Fiscal Period Ended June 30	Wine Gallons of Alcohol	Gallons of Witch Hazel Extract Manufactured, 14% Alcohol
1940 **	149,374	1,066,957
1941 **	118,986	849,900
1942 **	150,250	1,073,214
1943 **	75,280	537,714
1944 ***	91,257	651,835
1945 ***	129,970	928,344
1946 ***	150,537	1,075,264
1947 ***	117,703	840,734
1948 ***	90,297	644,978
1949 ***	112,616	804,400
1950 ***	95,358	681,128
1951 ***	133,654	883,242
1952 ****	94,530	732,357

** Two permittees reported.
*** Three permittees reported.
**** Four permittees reported. The fourth represents new owners of the distillery at Long Hill, Conn.

These data indicate that annual production of aqueous witch hazel is usually between half a million and a million gallons, that the million-gallon mark has been exceeded only in three years and

that not more than four concerns have been engaged in any one year in manufacturing the extract. Other reports (96), dealing with industrial uses of pure alcohol, make no mention of witch hazel and thereby indicate that there are not any additional manufacturers of the extract using pure instead of denatured alcohol.

Analyses

Analyses (31, 32) reveal that both bark and leaves of witch hazel contain a gallitannin, known as " hamameli tannin ", and traces of gallic acid, of a phlobatannin, of choline, of a glycoside, a saponin, a bitter principle and a volatile oil. Of these, tannin is the most abundant and most important medicinally, for it is the ingredient responsible for the astringent action of powdered leaves and bark and of concentrated extracts. Tannin does not come over with the distillate in manufacturing aqueous witch hazel, and the efficacy of the water extract has been attributed to the trace of volatile oil that may do so. The literature on the subject contains occasional statements to the effect, however, that an efficacious ingredient other than tannin has not yet been isolated from witch hazel.

The bark contains about 6% tannin, and the content in the leaves is generally higher though variable, depending on several factors. Several species of *Hamamelis* have been analyzed, the leaf content of tannin ranging from 2.27% to 9.47%; and in *H. vernalis*, the American species growing west of *H. virginiana* but apparently not being used for extraction, the content varied from 3.2% in April to 12.4% in October (32). The tannin content of a commercial batch of leaves was found to vary from 7.7% to 11% (32).

The aromatic principle, accounting for the characteristic aroma of the aqueous extract, has not been identified and apparently is not present in the dry bark but may be formed during maceration of the twigs in water (33).

The statement that witch hazel seeds contain a useful oil (25) has no confirmation in two standard works on essential oils (44, 57), and an extract has been reported to have given some antibiotic action in vitro (5).

Uses and Appraisals

The various preparations of witch hazel listed on a previous page have been compounded along with other ingredients into skin cosmetics (jellies, foams, creams, tonics, lotions, packs, powders), shaving products (brushless cream, after shaving lotions), mouth preparations, eye lotions, ointments and soaps (85). One recent author (85) has high praise for the alleged curative powers of styptic action of witch hazel in stopping nasal bleeding and hemorrhages in stomach, intestines, lungs and kidneys; and the astringent and healing effects, he writes, are shown in treating chapped skin, scratches, inflammatory wounds, swellings, ulcers and itching eczema. He attributes the curative powers to the tannic content and presumably to the minute amounts of volatile oil and fats. In further praise he says:

> " With the application of hamamelis, healing is promoted because of the rapid formation of tiny fleshy warts, which, owing to their enhanced expansion, close the wound and alternatively renew the destroyed skin. Another aspect of the healing action is the vascular restorative effect. Therapeutically, hamamelis-containing preparations are thus indicated as the treatment of choice for the satisfactory treatment of piles, vascular inflammations and varicose veins ".

The present author has been unable to find any testimony supporting this eulogy which conveys the impression that hamamelis-containing preparations offer the best treatment for the desig-

nated ailments. By way of contrast, the Dispensatory of the United States of America—24th Edition makes the following temperate admission:

> "The tannin content of hamamelis leaf fluid extract is sufficiently high to confer on it a mildly astringent action which is occasionally utilized".

But elsewhere it says:

> "Hamamelis is so nearly destitute of medicinal virtues that it scarcely deserves official recognition. The fluidextract is occasionally employed as a mild astringent; either it or a dry extract of the leaf is sometimes used as an ingredient of ointments or suppositories for the treatment of hemorrhoids".

The aqueous extract, popularly known merely as "witch hazel", has for generations been used as a soothing liniment for sore muscles and minor skin irritations from insect bites and sunburn to poison ivy. It has been used also as an after-shaving lotion, and has been recommended as a mouth wash and gargle. A recent book on treating canine ailments also recommends it (26). Such use as a household remedy in America undoubtedly will long continue despite the following derogatory appraisal by the U. S. Dispensatory which implies that it is no more than an "alcoholic rub":

> "This water was introduced on account of the large demand for it which grew out of the wide advertisements of a certain proprietary medicine, and the universally recognized need in American families for an embrocation which appeals to the psychic influence of faith. As the tannic acid of hamamelis bark does not come over into the distillate, the water is therapeutically a mixture of water and alcohol, the volatile oil being found in too minute a proportion to possess any therapeutic value".

There is little reason to expect this lack of scientific evidence in favor of aqueous witch hazel to result in diminution of consumption any more than the tobacco industry has suffered from the evils associated with smoking. Certainly nothing of ill repute as is associated with nicotine can be said of "witch hazel", and the well established traditional use of so innocuous a substance as this extract does not readily give way before the factual discrediting evidence of science, however valid that evidence may be.

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Literature Consulted

1. Adams, J. Medicinal plants and their cultivation in Canada. Canad. Dept. Agr., Dom. Exp. Farms. Ser. II. Bull. 23. 1915.
2. Allen, J. A. A synopsis of pharmacology. 63 pp. 1823.
3. Allport, N. L. The chemistry and pharmacy of vegetable drugs. 252 pp. 1944.
4. American druggist blue book. 1952.
5. d'Amico, Maria Luisa. Fitoterapia **21**: 77–79. 1950.
6. Anonymous. Report of the committee on indigenous medical botany. Trans. Am. Med. Assoc. **1**: 341–357. 1848.
7. ———. Science News Letter **36**: 194. 1939.
8. ———. Little journeys into chemurgic industries—Witch Hazel. Chemurgic Digest **2**: 193. 1943.
9. ———. Witch Hazel—Product of the soil. Rural New Yorker **101**: 367. 1942.
10. Aries, R. S. Extractives of Northeastern woods. Chemurgic Digest **4**: 153, 155–165. 1945.
11. ———. Extractives, a review of literature. *In* Extractives from Northeastern woods. Northeastern Wood Util. Coun., Bull. 9: 7–32. 1946.
12. ———. Extractives from Northeastern woods. Northeastern Wood Util. Coun., Bull. 9. 1946.
13. Baillon, H. Traité de botanique médicale phanérogamique. 1499 pp. 1884.
14. Balfour, J. H. Manual of botany. 1875.
15. Barton, B. S. Collections for an essay towards a materia medica of the United States. Part I, 1798; Part II, 1804.
16. Barton, W. P. C. Vegetable materia medica of the United States or medical botany. 2 Vols. 1817, 1818.
17. ———. Outlines of lectures on materia medica and botany. 2 Vols. 1827.
18. Bergen, Fannie D. Popular American plant names. I. Jour. Am. Folk-Lore **5**: 89–106. 1892; II. Bot. Gaz. **18**: 420–427. 1893; III. Bot. Gaz. **19**: 429–444. 1894; IV. Bot. Gaz. **22**: 473–487. 1896; V, VI. Bot. Gaz. **26**: 247–258. 1898.
19. Berry, H. Extract of Hamamelis. Pharm. Jour. IV. **83**: 247–248. 1936.
20. Bigelow, J. American medical botany. 1817–1820.
21. Blankenbiller, H. C. [Personal communication].
22. Buchan, W. Everyman his own doctor. 464 pp. 1816.
23. Carver, J. Travels through the interior parts of North America in the years 1766, 1767, and 1768. 1778.
24. Chamberlain, L. S. Plants used by the Indians of eastern North America. Am. Nat. **35**: 1–10. 1901.
25. Clements, Edith S., and F. C. Clements. Flower pageant of the midwest. Nat. Geog. **76**: 219–271. 1939.
26. de Bairacli-Levy. Medicinal herbs. Their use in canine ailments. 111 pp. 1948.
27. Dickinson, T. L. [Personal communication].
28. Directory of New England manufacturers—1952.
29. Drug topics red book. 1953.
30. Fountain, J. Remarks on the medicinal properties of witch hazel. N. Y. Jour. Med. **10**: 208–209. 1848.
31. Freudenberg, K. Hamamali tannin. Ber. Chem. Ges. I. **52B**: 177–185. 1919; II. **53B**: 953–961. 1920.
32. Ganday, R. The tannin content of Hamamelis leaves. Pharm. Jour. **156**: 72–73. 1946.
33. Gathercoal, E. N., and E. H. Wirth. Pharmacognosy. 2nd ed. 756 pp. 1947.
34. Gerarde, J. The herball or generall historie of plants. p. 1295, 1296. 1597. [Enlarged and amended by T. Johnson in 1633. p. 1481].
35. Gilmore, M. R. Chippewa uses of plants. Papers Mich. Acad. Sci., Arts & Letters **17**: 119–143. 1932.
36. Going, Maud. Field, forest and wayside flowers. 1899.
37. ———. With the trees. 1903.
38. Graves, A. H. A brief historical survey of the use of plants in medicine. Brooklyn Bot. Garden Rec. **32**: 169–186. 1943.
39. Gray, A. Selections from the scientific correspondence of Cadwallader Colden with Gronovius, Linnaeus, Collinson, and other naturalists. Am. Jour. Sci. & Arts **44**: 85–133. 1843.
40. ———. [Review of Henfry's book]. Am. Jour. Sci. & Arts **24**: 439. 1857.
41. Grieve, M. A modern herbal. 2 Vols. 1931.
42. Griffith, R. E. Medical botany. 704 pp. 1847.
43. Gronovius, J. H. Flora Virginica. Part 2: 139. 1743.
44. Guenther, E. The essential oils. Vol 5: 255. 1952.
45. Harriot, A. A briefe and true report of the new found land of Virginia etc. 33 pp. 1590.
46. Hartford Daily Courant. July 18, 1900; December 6, 1938.

47. Henfrey, A. An elementary course of botany; structural, physiological and systematic; with a brief outline of the geographical and geological distribution of plants. 702 pp. 1857.
48. Henkel, Alice. American medicinal barks. U. S. Dept. Agr., Bur. Plant Ind., Bull. 139. 1909.
49. ———. American medicinal leaves and herbs. U. S. Dept. Agr., Bur. Plant Ind., Bull. 219. 1911.
50. Henry, S. A new and complete American medical family herbal etc. 1814.
51. Héraud, A. Nouveau dictionnaire des plantes médicinales. 651 pp. 1927.
52. Hill, A. F. Economic botany. 592 pp. 1937.
53. Hilton, S. L. Aqua Hamamelidis N.F.—Hamamelis water, witch hazel water, distilled extract of witch hazel. Jour. Am. Pharm. Ass'n. **19**: 232–235. 1930.
54. Hopkins, G. M. Marketing forest products in New Hampshire. N. H. State Planning & Devel. Comm. [Mimeo., not dated].
55. Howard, H. An improved system of botanic medicine. Vol. 2. 458 pp. 1833.
56. Industrial Directory of Connecticut, 1947.
57. Jamieson, G. S. Vegetable fats and oils. 508 pp. 1943.
58. Johnson, L. A manual of the medical botany of North America. 292 pp. 1884.
59. Jowett, H. A. D., and F. F. L. Pyman. An examination of the essential oil of witch hazel. Pharm. Jour. **9**: 129–130. 1913.
60. Kalm, P. [A short account of the natural position, use, and care of some plants, of which the seeds were recently brought home from North America for the service of those who take pleasure in experimenting with the cultivation of the same in our climate]. 48 pp. 1751. [Trans. by Esther L. Larsen. Agr. Hist. **13**: 33–64. 1939].
61. Lee, J. An introduction to botany. 320+ pp. 1760. p. 253, 320.
62. Lindley, J. Flora medica. 632 pp. 1838.
63. ———. Vegetable kingdom. 1846.
64. Linnaeus, C. Genera plantarum. 2nd ed. Vol. 1: 54. 1742.
65. ———. Species plantarum. Vol. 1: 124. 1753.
66. Lloyd, J. U. Origin and history of all the pharmacopeial vegetable drugs. VIII and IX rev. 1929.
67. ——— and J. T. Lloyd. History of Hamamelis (Witch Hazel), extract and distillate. Jour. Am. Pharm. Assoc. **24**: 220. 1935.
68. Mercier, F., and J. Balansard. Sur les constituants de l'Hamamelis virginica. Compt. Rend. Soc. Biol. **121**: 671–672. 1936.
69. Millspaugh, C. F. American medicinal plants. Vol. 1: 58. 1887.
70. National Formulary. VIII ed. 1946.
71. Nelson, A. Medical botany. 544 pp. 1951.
72. Newman, J. B. The home doctor and book of herbs. 1861.
73. Osol, A., and G. E. Farrar. The dispensatory of the United States—24th Edition. 1928 pp. 1947.
74. Oxford dictionary of the English Language. 10 Vols.
75. Palmer, E. Plants used by the Indians of the United States. Am. Nat. **12**: 593–606, 646–655. 1878.
76. ———. Food products of the North American Indians. U. S. Comm. Agr., Rep. 1870: 404–428. 1871.
77. Peattie, D. C. Sassafras and witch hazel. Atlantic **182**(5): 69. 1948.
78. ———. A natural history of trees of Eastern and Central North America. 606 pp. 1950.
79. Pharmacopoeia of the United States of America.
80. Plukenet, L. Almagestrum Botanicum. p. 298. 1696.
81. Rafinesque, C. S. Medical flora. 268 pp. 1828.
82. Ray, J. Historia plantarum. Vol. 2: 1926–1928. 1688.
83. Rehdern, W. [*Hamamelis virginica* L. as an active cosmetic material]. Seifensieder Zeit. **66**: 294–295, 314–315. 1939. [From Chem. Abs. **33**: 9548. 1939].
84. Rose, E. S. Testing some common antiseptics. Am. Jour. Pharm. **101**: 52–55. 1929.
85. Ruemele, T. Hamamelis (Witch Hazel). Perf. & Ess. Oil Rec. **41**: 323–325. 1950.
86. Sargent, C. S. Silva of North America. Vol. 5. 1893.
87. Schery, R. W. Plants for man. 564 pp. 1952.
88. Scoville, W. L. Oil of *Hamamelis virginiana*. Proc. Am. Pharm. Assoc. **55**: 448–449. 1907. Am. Jour. Pharm. **79**: 496. 1907.
89. Seybert, J. E. [Personal communication].
90. Sievers, A. F. The production of minor essential oils in the United States. Econ. Bot. **1**: 148–160. 1947.
91. Smith, H. H. Ethnobotany of the Me-

nominee Indians. Bull. Pub. Mus. Milwaukee 4(1): 1–174. 1923.
92. ———. Ethnobotany of the forest Potawatomi Indians. Bull. Pub. Mus. Milwaukee 7(1): 1–230. 1933.
93. Thomas' Register of American Manufacturers. Dec. 1951 Edition.
94. Trease, G. E. A textbook of pharmacognosy. 5th ed. 811 pp. 1949.
95. U. S. Treasury Dept., Bur. Int. Rev., Alcohol Tax Unit (1940–1950), Alcohol and Tobacco Tax Division (1951–1952). Statistics on the use of specially denatured alcohol.
96. ———. Statistics on alcohol.
97. Van Wijk. A dictionary of plant names. 2 Vols. 1911.
98. Waugh, E. W. Iroquois foods and food preparations. Geol. Survey Canada, Dept. Mines, Mum. 86. 1916.
99. Webster's New International Dictionary.
99a. Woodward, E. F. [Personal communication].
100. Yosida, Y. Pharmacognostic study of the leaves of *Hamamelis* species. II. Jour. Pharm. Soc. Japan **59**: 656–659. 1939. Chem. Abs. **34**: 1130. 1940. III, IV. Jour. Pharm. Soc. Japan **61**: 431–437, 437–440. 1941. Chem. Abs. **44**: 9632. 1950.
101. Youngken, H. W. The drugs of the North American Indians. Am. Jour. Pharm. **96**: 485–502. 1924; **97**: 158–185, 257–271. 1925.
102. ———. Textbook of pharmacognosy. 5th ed. 1038 pp. 1943.
103. ———. [Personal communication].
104. Zollickoffer, W. A materia medica of the United States. 120 pp. 1819.

Utilization Abstracts

British Guiana Woods. As part of a program to promote chemical utilization of tropical hard woods, the British Forest Products Research Laboratory, Princes Risborough, England, has investigated the resin-yielding potentialities of Wallaba (*Eperua* sp.) and the saponin-producing possibilities of mora (*Mora excelsa*) and morabukea (*M. gonggrijpii*), trees of British Guiana. (R. H. Farmer and W. G. Campbell, *Tappi 53(4): 178. 1952*).

Bagasse Paper. In 1939 W. R. Grace & Co. built a paper mill at Paramonga, in the coastal lowland of Peru, and has since then been producing paper there from bagasse, the residue of sugar cane after extraction of sugar. "This base material, formerly rated suitable only as animal fodder or fuel for the sugar factory's boilers, is now finding its way into such items as grocery bags, cigarette packages and candy wrappers, cardboard, cartons, copy paper, newsprint, and blue paper for wrapping cotton". A four-page uncoated insert of such paper carries this article in an otherwise coated-stock periodical. (Anon., *Pulp and Paper Mag. of Canada 53(11): 83. 1952*).

Rice Bran Oil Wax. A hard wax, with possible commercial value, can be refined from tank settlings of crude rice bran oil. (E. R. Cousins, S. P. Fore, H. J. Janssen and R. O. Feuge, *Jour. Am. Oil Chem. Soc. 30(1): 9. 1953*).

Osage Orange Antioxidant. The spherical fruits of osage orange (*Maclura pomifera*), up to three pounds in weight, contain about ten percent by weight of an antioxidative component that may be of commercial value in preventing rancidity in oil-soluble vitamin concentrates, cosmetics, pharmaceuticals, lubricating greases and many other substances subject to oxidative deterioration. (J. R. Clopton, *Jour. Am. Oil Chem. Soc. 30(4): 156. 1953*).

Camphor. Four groups of camphor tree, all of the same species (*Cinnamomum Camphora* Sieb.), are distinguishable on the basis of botanical differences and of differences in the leaf oils. One of the groups, the Japanese camphor tree, is not subject to further subdivision, and its leaf oil contains free crystalline camphor. The New Zealand, the Formosan West and the Formosan East are the other three groups. The latter two may be further subdivided according to their oil content of camphor, cineole, safrole, linolol, borneol and other components. (N. Hirota, *Perf. & Essen. Oil Rec. 44(1): 4. 1953*).

A Genic Substitute for Isolation in Hybrid Corn Seed Production

Complete isolation of production fields for hybrid corn seed is difficult to attain in our Middle West. When the seed being produced is field corn seed and it is fertilized by other field corns, contamination is difficult to detect and not very serious. But when the seed being grown is of a specialized type, such as popcorn or waxy corn, outcrossing is most detrimental. A practical solution to this isolation problem lies in a unique type of cross-sterility discovered in some of our popcorns.

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Introduction

Besides providing a pleasant adjunct to an evening's cinematic entertainment, the popcorn branch of the corn genus has some special features that make it uniquely interesting to the geneticist and the plant breeder. Investigators long have surmised that the popcorns are a primitive group and may represent the sources from which our modern varieties of corn have evolved over the centuries. As a partial confirmation of this, archaeological studies have revealed that the maizes which were the mainstay of primitive American agriculturalists were popcorns. But their evolution into the corns we know today has been an involved progression, concerning which we have only circumstantial evidence.

The popcorns are set apart from other maize in another important characteristic. It has been found recently here at Purdue that when most popcorn varieties are pollinated by field corn pollen, little or no seed set results. The first instance of this type of incompatibility was noted by M. Demerec in 1929 (1). When field corn is used as the female parent and popcorn as the male parent, attempts to cross the two strains result in a perfect set of seed. This situation (the ability to cross these particular popcorns with field corn if the popcorn is used as the male parent but not if it is used as the female parent) is known as non-reciprocal cross-sterility.

This inability to set seed with field corn pollen is typical of most popcorns from South America as well as most open-pollinated varieties which have some commercial importance in this country. Among our more familiar popcorns which are cross-sterile are South American, Hulless, Black Beauty, Strawberry, Baby Golden, Red, White Pearl and Ohio Yellow. The most familiar variety which is not cross-sterile is Supergold. All the varieties which are cross-sterile cross freely among themselves regardless of the direction in which the cross is made.

The inability of field corns to pollinate a cross-sterile popcorn is apparently a general one. Using several Hulless inbreds as testers, a wide range of field corn inbreds were unable to induce seed set. Among these were Hy, Tr, A, C103, M14, WF9, L317, Os420, 38-11, 187-2, 33-16, K41 and H21. The inbreds tested do not comprise a large fraction of those available, but it is significant that no North American field corn tested

can fertilize these popcorns, and there are valid genetic reasons for believing that we shall not find any field corns in this country that are capable of inducing seed set. The North American flints and sweet corns which have been tried also are unable to effect fertilization.

Genetic Background

The genetic background of this situation has been investigated at the University of Illinois (3) and at Purdue (2), and cross-sterility has been found to be simply inherited. All the cross-sterile popcorns are Ga^s/Ga^s, while all tested field corns are ga/ga. To translate our previous notes into genetic terminology, the cross $ga/ga \times Ga^s/Ga^s$ can be made, while the reciprocal, $Ga^s/Ga^s \times ga/ga$, cannot. Plants which are the result of a cross between a field corn and a popcorn and are ga/Ga^s can usually set seed perfectly either with field corn pollen ga or with popcorn pollen Ga^s. When, however, both field corn pollen (ga) and popcorn pollen (Ga^s) are applied together to the silks of plants of this type, it becomes evident that the field corn pollen is at a great competitive disadvantage, since in almost 100 percent of the kernels the popcorn pollen has affected fertilization.

From a biological viewpoint this type of cross-sterility is rather unusual. In naturally cross-pollinated species it is not uncommon to find that genetic systems have arisen which guard against self-pollination. It is much less common to find genetic barriers against crossing, even though these barriers are effective in only one direction. Why most popcorns but none of our North American field corns show cross-sterility, is a question that our theories of the evolution of modern types of corn must consider. Cross-sterility is such a good marker that it will make an excellent genetic tool for tracing some of the proposed evolutionary steps in the development of maize.

Practical Applications

Beyond these intriguing questions of where cross-sterility arose and what its evolutionary significance may be, lies the fact that this unusual one-way incompatibility has some practical uses in modern corn-breeding and production. The cross-sterility allele Ga^s has definite applications in both seed production and commercial production of hybrids which are to be grown for a particular endosperm type. In spite of the fact that most popcorns will not accept dent corn pollen, the greatest problem in the production of hybrid popcorn seed is contamination by dent corn pollen. This situation arises because many of the best popcorn inbreds come from the variety Supergold which is one of the few popcorns known to be ga/ga. They are, therefore, perfectly fertile with field corn pollen. The major commercial hybrids have been three-way crosses of the type (Supergold inbred × Supergold inbred) × South American inbred. Since South American inbreds are as sterile with pollen from Supergold inbreds as they are with field corn pollen, the crosses must be made, as indicated above, with the South American inbred as the pollinator.

These Supergold single crosses which are used as the female parents in seed production are thus fertile with the dent corn pollen which is always present to some extent, since complete isolation from field corn cannot be obtained in the Corn Belt. The kernels from ovules fertilized by field corn cannot be distinguished from those fertilized by the desired popcorn parent. When planted, however, they produce hybrid plants with ears intermediate between dent corn and popcorn which are worthless for popping purposes. These "horsecorn" ears must be separated from the popcorn ears before processing. This situation has proved to be a serious problem both to the hybrid popcorn seed grower and to the commercial popcorn

producer. In extreme cases the percentage of contamination in seed produced in poorly isolated fields has exceeded 25 percent, thus lowering the value of the crop produced from the seed by nearly that amount in addition to the labor expended in the necessary separation of the contaminants.

It is, however, proving to be a simple matter to transfer the factor for cross-sterility (Ga^s) to these Supergold inbreds, thus insuring in a production field that the female plants would set seed only with pollen from the male rows (South American and hence Ga^s) and not with any dent pollen which should happen to drift into the field. Alternatively, the cross-sterile South American types could then be used as females, since the recovered Supergold inbreds would be able to pollinate them. This conversion of parent inbreds is nearly complete, and in the near future, hybrids free from field corn contamination should be available. Another lead being followed toward the production of dent-free hybrids is to intensify the search for good inbreds in varieties that are already dent-sterile.

More and more breeding work is being directed towards the production of field corn hybrids with special chemical constituents in the seed (*e.g.*, waxy, high amylose, etc.). These special types are much desired by processors as the raw materials for specialized manufacturing procedures. The genes controlling these variations in the chemical composition of the seed are genetically recessive, which means that fertilization by pollen from the usual, starchy, field corns results in the production of a starchy seed. There are two chances for undesirable outcrossing to occur—first in the production of seed, secondly in the crop being grown for processing. In some instances, contamination of the seed crop is detectable, and the crossed (starchy) kernels can be sorted out by hand. This separation, however, is tedious, expensive and never completely effective. In the crop being grown for processing where dent corn pollen drifts into the field and effects fertilization, it reduces the value of the crop proportionally to the extent of fertilization with that pollen, since the outcrossed kernels will all have starchy endosperms, and if contamination is above tolerance limits, may seriously interfere with the uses for which the particular type of corn is being grown.

Outcrossing at both these stages would be eliminated if the cross-sterility factor Ga^s were transferred into all the inbreds comprising such hybrids. Then through all the steps of seed production and commercial production, these cross-sterile types would be incapable of setting seed with drifting field corn pollen. With the increased breeding of hybrids for special endosperm characters, and the difficulty of isolating seed production fields of such hybrids from others which are a source of contaminating pollen, it would seem well worthwhile to expend the little effort required to transfer the cross-sterility factor into all such inbreds, thus achieving genetic isolation.

Cross-sterility, its origin and its distribution represent a fascinating puzzle which when solved may provide valuable clues to the development of our most valuable economic plant. That it, incidentally, has practical applications of a specialized sort, provides another example of the fact that once the theoretical basis of a genetical problem has been worked out, valuable solutions to practical breeding problems may not be far behind.

Literature Cited

1. Demerec, M. Cross sterility in maize. Zeit. Ind. Abst. Ver. **50**: 281–291. 1929.
2. Nelson, O. E. Non-reciprocal cross-sterility in maize. Genetics **37**: 101–124. 1952.
3. Schwartz, D. The analysis of a case of cross-sterility in maize. Proc. Nat. Acad Sci. **36**: 719–724. 1950.